# REVIEW OF THE LITERATURE ON THE BIOLOGY OF TASMANIAN NATIVE FRESHWATER FISH.

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# CHAPTER 1 INTRODUCTION

Although Tasmania posesses a large amount of freshwater and a considerable variety of freshwater habitats it does not have a correspondingly large native freshwater fish fauna. The fauna is low in species number and also lacks diversity.

Twenty five species are recognised in this work as native "freshwater" fishes. The term freshwater cannot be used too rigidly as many other species of fish may spend part of their life in freshwater ( water with salinity below 3p.p.t. is henceforth used to define freshwater). All of the fish included in the review with the possible exception of the whitebait, Lovettia sealii (Johnston) would appear to require or perhaps prefer freshwater for part or all of their life. Lovettia sealii has traditionally been included in works on freshwater fish in Tasmania and it is therefore included with that group in this work.

Of the 25 species, 18 are of the order Salmoniformes, suborder Galaxioidei (McDowall 1969) and no less than 10 are of the genus Galaxias. The remaining 7 species are spread through 3 orders as follows: Petromyzoniformes (2 species), Anguilliformes (2 species) and Perciformes (3 species).

The fauna shows an amazing radiation in the galaxiid group but suprisingly little activity elsewhere. In fact all of the 13 species endemic to the State are galaxioid fishes. However there has been little study of any detail done in Tasmania on any of the native freshwater fishes.

The only exception to this is the work by Blackburn (1950) on L. sealii. With the exception of some brief, scattered details on some species all knowledge of the Tasmanian native fishes is a result of work done elsewhere in Australia and New Zealand.

It is beyond the intended scope of this thesis to include a review of all the taxonomic work on the native freshwater fish of Tasmania as this would be as voluminous as the biological data.

The treatment of the taxonomic data will be in the form of a species list as seen at the present time with a separate synonomy giving names and first user only for each species, then a brief coverage of the major taxonomic changes that have occurred since the original description of each species.

The literature search relied heavily on the extensive reference lists in many papers by McDowall ( in particular: 1964a, 1968b, 1970c, 1971a, 1972a, b, 1976c) and in the papers directly relating to the Tasmanian fauna by Frankenberg (1974) and Andrews (1976).

## 1.1 List of Tasmanian Native Freshwater Fish Species

Order Petromyzoniformes

Family Geotriidae

Geotria australis Gray: (pouched lamprey)

Family Mordaciidae

Mordacia mordax (Richardson): (short headed lamprey)

Order Anguilliformes

Family Anguillidae

Anguilla australis Richardson: (short finned eel)

A. reinhardtii Steindachner: (long finned eel)

Order Perciformes

Family Kuhliidae

Nannoperca australis Gunther: (pygmy perch)

Family Gadopsidae

Gadopsis marmoratus Richardson: (blackfish)

Family Bovicthyidae

Pseudaphritis urvillii (Cuv & Val.): freshwater flathead, sandy

Order Salmoniformes

Suborder Galaxioidei

Family Galaxiidae

Galaxias auratus Johnston: (golden galaxias)

G. brevipinnis Günther : (climbing galaxias)

G. cleaveri Scott: (mud fish)

G. fontanus Fulton

G. johnstoni Scott: (Clarence galaxias)

G. maculatus (Jenyns): (Jollytail)

G. parvus Frankenberg

G. pedderensis Frankenberg

G. tanycephalus Fulton

G. truttaceus Valenciennes: (spotted galaxias)

Galaxiella pusilla (Mack): (dwarf galaxias)

Paragalaxias dissimilis (Regan)

P. eleotroides McDowall & Fulton

P. julianus McDowall & Fulton

P. mesotes McDowall & Fulton

Family Aplochitonidae

Lovettia sealii Johnston: (whitebait)

Family Prototroctidae

Prototroctes maraena Günther: (grayling)

Family Retropinnidae

Retropinna tasmanica McCulloch: (smelt)

The non galaxiid section of the list has been compiled largely after Frankenberg (1974). The galaxiid list essentially follows the revision by Andrews (1976) with additional Galaxias species (Fulton 1978a,b) and changes to the Paragalaxias genus (McDowall & Fulton 1978a,b) and removal of Galaxias pusillus to the newly created genus Galaxiella (McDowall 1978b).

The subspecific classification in Anguilla and Nannoperca is not recognised as being of significant importance to warrant separate treatment.

## 1.2 Synonomy

As mentioned above the synonomies contain only the references to the first user of each of the synonyms. In some cases there was conflict in the literature as to the validity of a certain synonomy hence there may be some innaccuracy in the lists which could be corrected only after considerable study.

Geotria australis Gray

Geotria australis Gray 1851

Velasia chilensis Gray 1851

Thysanochilus valdivianus Troschel 1857

Petromyzon fonki Philippi 1865

Petromyzon macrostomus Burmeister 1868

Geotria allporti Gunther 1870

Geotria chilensis Gunther 1872

Yarra singularis Castelnau 1872

Neomordacia howittii Castelnau 1872

Exomegas macrostoma Gill 1883

Geotria macrostoma Berg 1893

Velasia stenostomus Ogilby 1896

Macrophthalmia chilensis Plate 1897

Exomegas macrostomus Berg 1899

Geotria stenostomus Waite 1904

Geotria saccifera Regan 1911

Dionisia patagonica Lahille 1915

Geotria australis Lord & Scott 1924

Mordacia mordax (Richardson)

Petromyzon mordax Richardson 1848

Mordacia mordax Gray 1851

Caragola mordax Waite 1921

Anguilla australis Richardson

Anguilla australis Richardson 1848

Anguilla schmidtii Phillipps 1926

Muraena australis Fowler 1928

Anguilla australis forma occidentalis Schmidt 1928b

Anguilla australis forma orientalis Schmidt 1928b

Anguilla australis australis Griffin 1936

Anguilla australis schmidtii Griffin 1936

## *Anguilla reinhardtii* Steindachner

*Anguilla reinhardtii* Steindachner 1867

*Anguilla mauritiana* Gunther 1880 (misidentification)

*Anguilla amboinensis* Klunzinger 1880 (misidentification)

*Anguilla reinhardtri* Macleay 1884 (misspelling?)

*Anguilla marginipinnis* Macleay 1884

*Muraena reinhardti* Fowler 1928

*Anguilla reinhardti* Schmidt 1928b

## *Nannoperca australis* Gunther

*Nannoperca australis* Gunther 1861

*Microperca yarrae* Castelnau 1872

*Paradules leetus* Klunzinger 1872

*Paradules laeus* Klunzinger 1880

*Nannoperca riverinae* Macleay 1881a

*Microperca tasmaniae* Johnston 1883

*Nannoperca* (*Nannoperca*) *australis* McCulloch & Waite 1918

*Nannoperca* (*Nannoperca*) *tasmaniae* McCulloch & Waite 1918

*Nannoperca tasmaniae* Lord 1923

*Nannoperca australis australis* Munro 1961

*Nannoperca australis tasmaniae* Munro 1961

*Nannoperca australis flindersi* Scott 1971a

## *Gadopsis marmoratus* Richardson

*Gadopsis breviceps* Agassiz 1845 (nomen nudum)

*Gadopsis marmoratus* Richardson 1848

*Gadopsis gracilis* McCoy 1879

*Gadopsis gibbosus* McCoy 1879

Gadopsis fuscus Steindachner 1884

Gadopsis tasmanicus Lynch 1966

Pseudaphritis urvillii (Cuv. & Val)

Aphritis urvillii Cuvier & Valenciennes 1831

Pseudaphritis bassii Castelnau 1872

Aphritis dumerili Gunther 1874

Uphritis urvillii Johnston 1883

Aphritis bassii Ogilby 1890

Pseudaphritis urvillii Ogilby 1898

Pseudaphritis urvillei Hall 1899 (misspelling)

Pseudaphritis urvilli Lord 1923

Pseudaphritis urvvilli Lord and Scott 1924 (misspelling)

Pseudaphritis bursinus Whitley 1955

Pseudaphritis ursinus Frankenberg 1974 (Fig 5.12)

Pseudaphritis d'urvillii Weatherley 1974

Pseudaphritis burvilli Chessman & Williams 1974 (misspelling)

Galaxias auratus Johnston

Galaxias auratus Johnston 1883

Galaxias (Galaxias) auratus Scott 1936a

Galaxias truttaceus truttaceus Lynch 1968a (misidentification)

Galaxias brevipinnis Gunther

Galaxias brevipinnis Gunther 1866

Galaxias olidus Hutton 1872 (not G. olidus Gunther 1866)

Galaxias campbelli Sauvage 1880

Galaxias coxii Macleay 1881a

Galaxias weedoni Johnston 1883

Galaxias atkinsoni Johnston 1883

Galaxias nigothoruk Lucas 1892

Galaxias lynx Hutton 1896

Galaxias robinsoni Clark 1899

Galaxias bollansi Hutton 1901

Galaxias huttoni Regan 1905

Galaxias affinis Regan 1905

Galaxias weddoni Lord 1927 (misspelling)

Galaxias (Galaxias) parkeri Scott 1936a

Galaxias (Galaxias) affinis Scott 1936a

Galaxias (Galaxias) weedoni Scott 1936a

Galaxias brevipinnis McFarlane 1939 (misspelling)

Galaxias parkeri Whitley 1956a

Galaxias castlae Whitley & Phillips 1940

Galaxias koaro Phillipps 1940

Galaxias kaikorai Whitley 1956b

Galaxias coxi Frankenberg 1974

Galaxias brevipinis Lynch 1978

## Galaxias cleaveri Scott

Galaxias cleaveri Scott 1934

Saxilaga (Saxilaga) cleaveri Scott 1936a

Saxilaga (Saxilaga) anguilliformis Scott 1936a

Galaxias (Galaxias) upcheri Scott 1942b

Galaxias anguilliformis Stokell 1959

Galaxias upcheri Whitley 1956a

Saxilaga cleaveri Whitley 1956a

Saxilaga anguilliformis Whitley 1956a

## Galaxias fontanus Fulton

Galaxias fontanus Fulton 1978b

## Galaxias johnstoni Scott

Galaxias (Galaxias) johnstoni Scott 1936a

Galaxias johnstoni Whitley 1956a

## Galaxias maculatus (Jenyns)

Mesites maculatus Jenyns 1842

Mesites alpinus Jenyns 1842

Mesites attenuatus Jenyns 1842

Galaxias attenuatus Valenciennes in Cuv. & Val. 1846

Galaxias scriba Valenciennes in Cuv. & Val. 1846

Galaxias minutus Phillippi 1858

Galaxias punctulatus Phillippi 1858

Mesites gracillimus Canestrini 1864

Galaxias krefftii Gunther 1866

Galaxias punctatus Gunther 1866

Galaxias pseudoscriba McCoy 1867

Galaxias waterhousei Krefft 1867

Galaxias forsteri Kner 1867 (in part)

Galaxias obtusus Klunzinger 1872

Galaxias versicolor Castelnau 1872

Galaxias cylindricus Castelnau 1872

Galaxias delicatulus Castelnau 1872

Galaxias amaenus Castelnau 1872

Galaxias coppingeri Gunther 1881

Galaxias nebulosa Macleay 1882

Austrocobitis attenuatus Ogilby 1899

Galaxeus attenuatus Noetling 1911 (misspelling)

Galaxias variegatus Lahille 1923

Galaxias titcombi Eigenmann 1928 (in part)

Galaxias attenuata Gray 1930

Austrocobitis attenuatus scriba Whitley 1933

Galaxias (Galaxias) attenuatus Scott 1936a

Galaxias parrishi Stokell 1964

Galaxias maculatus attenuatus Stokell 1966

Galaxias maculatus maculatus Stokell 1966

Galaxias maculatus ignotus Stokell 1966

Galaxias usitatus McDowall 1967a

Galaxias maculatus McDowall 1967a

Galaxias attenuatus scriba Scott 1968

Galaxias maculatus scriba Frankenberg 1974

Galaxias parvus Frankenberg

Galaxias parvus Frankenberg 1968

Galaxias pedderensis Frankenberg

Galaxias pedderensis Frankenberg 1968

Galaxias tanycephalus Fulton

Galaxias tanycephalus Fulton 1978a

Galaxias truttaceus Valenciennes

Esox truttaceus Cuvier 1817 (nomen nudum)

Galaxias truttaceus Valenciennes in Cuvier & Val. 1846

Galaxias forsteri Kner 1867 (in part)

Galaxias ocellatus McCoy 1867

Galaxias truttaceous Anderson 1900

Galaxias (Galaxias) truttaceus Scott 1936a

Galaxias (Galaxias) scopus Scott 1936a

Galaxias scopus Whitley 1944

Galaxias truttaceus hesperius Whitley 1944

Galaxias hesperius Whitley 1956a

Galaxias truttaceus scopus Munro 1957b

Galaxias truttaceus truttaceus Munro 1957b

Galaxiella pusilla (Mack)

Galaxias pusillus Mack 1936

Galaxias pucillus Mack 1936 (misspelling)

Galaxias puccillus Stokell 1938 (misspelling)

Galaxias ornatus Whitley 1939 (not G. ornatus Castelnau 1873)

Brachygalaxias pusillus Scott 1942b

Galaxias pusillus pusillus Shipway 1953

Brachygalaxias pusillus pusillus Munro 1957a

Brachygalaxias pusillus tasmaniensis Scott 1971b

Brachygalaxias pusillus flindersiensis Scott 1971b

Galaxiella pusilla McDowall 1978b

Paragalaxias dissimilis (Regan)

Galaxias dissimilis Regan 1905

Paragalaxias shannonensis Scott 1935a

Querigalaxias dissimilis Whitley 1935a

Paragalaxias dissimilis Stokell 1950

Paragalaxias eleotroides McDowall & Fulton

Paragalaxias shannonensis Stokell 1950 (misidentification)

Paragalaxias eleotroides McDowall & Fulton 1978a

Paragalaxias julianus McDowall & Fulton

Paragalaxias julianus McDowall & Fulton 1978b

Paragalaxias mesotes McDowall & Fulton

Paragalaxias shannonensis Scott 1966 (misidentification)

Paragalaxias mesotes McDowall & Fulton 1978a

Lovettia sealii (Johnston)

Haplochiton sealii Johnston 1883

Haplochiton seali Saville-Kent 1897

Aplochiton seali Ogilby 1908

Lovettia sealii McCulloch 1915

Lovettia seali Lord 1923

Prototroctes maraena Gunther

Prototroctes maraena Gunther 1864

Prototroches marena Noetling 1911 (misspelling)

Protatroctes maraena Lord & Scott 1924 (misspelling)

Prortoctes maraena Munro 1957a (misspelling)

Retropinna tasmanica McCulloch

Retropinna richardsonii Johnston 1883

Retropinna tasmanica McCulloch 1920

## 1.3 Taxonomic History.

The lamprey group has suffered many revisions from the familial to the specific level. Hardisty & Potter (1971) found that there had been no uniform agreement on the familial placement of the two southern hemisphere genera Geotria and Mordacia. Rauther (1924), Holly (1933), Berg (1940) and Fontaine (1958) have separated Mordacia from both Geotria and and the northern hemisphere forms at the subfamilial level whereas others have placed it in a distinct family (Gill 1893; Ogilby 1896; Waite 1921). Nichol'skii (1954) placed both southern genera in a single subfamily whereas Eigenmann (1928),

McCulloch (1929), Fowler (1940), Buen (1961) and Scott (1962), placed them in a single family. A tripartite division at the familial level was suggested by Whitley (1932) and Hubbs (1947). A similar division but at the subfamilial level was adopted by Potter and Strahan (1968) after comparison of various anatomical and morphological factors. However after further and extended analysis of these features a tripartite division at the familial level was again proposed (Hardisty & Potter 1971). Hence, the present taxonomic state of the lampreys (after Hardisty & Potter 1971) has all the northern genera in the family Petromyzonidae and the two southern genera in the separate families Geotriidae and Mordaciidae.

The southern hemisphere families were split into numerous different genera and species largely due to failure of early workers to recognise the different morphological stages in the lamprey life cycle (Strahan 1959, Buen 1961; Potter & Strahan 1968).

Nine different names have been used for the genus Geotria and at least 12 specific names (see synonomy listed above) but at present the genus is monospecific. Mordacia has been less confused although it was first placed in the northern hemisphere genus Petromyzon by Richardson (1848). Three species are now known in the genus, all of which are confined to the southern hemisphere.

The taxonomy of Tasmanian freshwater eels has seen little change in contrast to the lampreys. The long-finned eel Anguilla reinhardtii has remained as such since first described (Steindachner 1867) with only limited misidentifications and synonyms (Schmidt 1928; Ege 1939). However the last "i" of the name has frequently been omitted (eg. Schmidt 1928b).

Anguilla australis was used as a collective name for all the many Indo-Pacific short-finned species described by early authors (Weber 1912; Boulenger 1915; Weber & Beaufort 1916). Schmidt (1925) indicated however that this species required some subdividing which he later did (Schmidt 1928a,b) creating A. australis forma occidentalis and forma orientalis for the Australian and New Zealand forms respectively.

The subspecific distinctions were maintained by Griffin (1936) however he pointed out that Schmidt (1928) had erred in his nomenclatural procedure and that the names should be A. australis australis for the Australian form and A. australis schmidtii for the New Zealand form. Further comprehensive review of this species is given by Ege (1939).

The subspecific classification has met with a mixed reception in recent work being adopted by some (McDowall 1966b; Frankenberg 1974; Todd 1976a; Jellyman 1977a) and not by others (Stokell 1955; Lake 1971; McDowall & Whitaker 1975). For this work subspecific differences are not recognised.

The genus Nannoperca was first described by Gunther (1861) as was the species N. australis from Victorian material. Johnston (1883) described a species from Tasmania as Microperca tasmaniae the genus having been erected by Castelnau (1872) for a Victorian species apparently without reference to Gunther's earlier work. Other synonomous species had been described from mainland Australia by Macleay (1881b) and Klunzinger (1872).

The similarity of N. australis and N. tasmaniae was probably first indicated by McCulloch and Waite (1918) when they did not distinguish between the two in their key to the genus. Later Waite (1921) thought that the two species may

be synonomous as did Whitley (1929a) but this was not agreed with by McCulloch (1929) in his checklist.

As indicated by Scott (1971a) the familial status of the genus has also been the subject of considerable controversy. It has been placed in the Percidae (Johnston 1891), Centrarchidae (McCulloch & Waite 1918), Serranidae (Lord 1923; Lord & Scott 1924; Berg 1940), Hyperlectrodidae (McCulloch 1929; Scott 1942a), Nannatherinidae (Whitley 1960) and Nannopercidae (Munro 1961; Scott,T.D. 1962; Scott,E.O.G. 1971a), but the placement which appears to have received the most recent following is in the family Kuhliidae (McCulloch 1927; Greenwood et al. 1966; Lake 1971; Frankenberg 1974) and this placement is followed here.

It must be said that many of the taxonomic problems and confusion arose due to mistakes in early descriptions and also the failure of many of these workers to lodge type material. Scott (1935b, 1942a) could not find grounds for distinguishing between the Tasmanian and mainland forms of Nannoperca but later Munro (1961) differentiated between these forms at the subspecific level proposing that the mainland form be N. australis australis Gunther and the Tasmanian (including King Island) form be N. australis tasmaniae Johnston. After this Scott took to the species and proposed a further subspecies N. australis flindersi (Scott 1971a).

Thus the present state of the taxonomy lists three subspecies of N. australis which were recognised in the latest comprehensive work on the Tasmanian fauna (Frankenberg 1974). These differences are not recognised in this review and I feel a thorough examination of more material from more

localities over the entire range of the species would show considerable overlap in the characters used for subspecific definition.

The river blackfish was described as Gadopsis marmoratus by Richardson (1848) and it is still known by that name. Two other Victorian species, G. gibbosus and G. gracilis, were described by McCoy (1879) and a further species (G. fuscus) was described from South Australia by Steindachner (1884). These species were discarded by later authors (Johnston 1883; Ogilby 1913) as being variants of the one species.

The Victorian and Tasmanian forms came under closer scrutiny by Parrish (1966) and were the subject of anMSc thesis. Parrish concluded that there were two separate species of Gadopsis however the work has not been formerly published. Some authors have since incorrectly used the name G. tasmanicus proposed by Parrish (1966) in his unpublished work (eg. Lynch 1966, 1968, 1969, 1974; Lake 1971).

In contrast to the specific name, the placement of the family Gadopsidae has been the subject of many works. These are best summarised by Parrish (1966) who concluded that Gadopsis should receive familial status and be included in the superfamily Trachinoidae (after Berg 1947).

The sandy appears to have been first described as Aphritis urvillii by Cuvier and Valenciennes (1831) although it is possible that it may be a synonym of the earlier described Eleginus bursinus (Cuv. & Val. 1830) from Port Jackson, New South Wales (see Ogilby 1898; Scott 1960). Castelnau (1872) described the genus Pseudaphritis in which he placed P. bassii collected from Bass Strait. Macleay (1882) recognised both

A. urvillii and P. bassii. Johnston (1883, 1891) did not mention this description but retained A. urvillii in the first paper and called the species Uphritis urvillii in the later paper. Ogilby (1890) did not recognise the genus Pseudaphritis but recognised the two species Aphritis urvillii and A. bassii. Berg (1895) found that the genus Aphritis was already occupied and therefore placed all species of that genus in the new genus Phricus. Later Ogilby (1898) reexamined the Australian form, finding only one species which he placed in Pseudaphritis as the next valid name. P. urvillii has been recognised by the majority of the authors since, (Regan 1910; Waite 1923; Lord & Scott 1924; McCulloch 1929; Scott 1953, 1960) and although recent authors have basically retained this name they have frequently dropped the last "i" of urvillii for some reason (see Lake 1971; Chessman & Williams 1974; Frankenberg 1974; Scott et al. 1974; Sloane 1976; Lake & Bennison 1977). Another variant of this is P. urvillei used by Hall (1899) and Johnston and Mawson (1940). The only persistent exception is Whitley who has consistently used the name P. bursinus (eg. Whitley 1955, 1960) referring to the specific name of the Cuvier and Valenciennes (1830) species.

The suborder Galaxioidei (after McDowall 1969) has by far the largest representation in the native freshwater fauna of the State and the taxonomy of the group at all levels has been the subject of many papers.

Their classification has been worked by various authors in recent times (Bertin and Arambourg 1958; Gosline 1960; Greenwood et al. 1966; Weitzman 1967; McDowall 1969) and various arrangements have been proposed. The classification

of McDowall (1969) has been adopted here and the suborder is represented in Tasmania by the families Galaxiidae, Aplochitonidae Prototroctidae and Retropinnidae.

The first record of galaxiid fishes is that of Forster (1777) who collected small "esox" like fishes from Dusky Bay New Zealand. The genus Galaxias was erected by Cuvier (1817) and the family Galaxiidae established by Muller (1844).

Many generic descriptions followed that of Cuvier, Neochanna (Gunther 1867), Brachygalaxias (Eigenmann 1928), Nesogalaxias (Whitley 1935), Paragalaxias (Scott 1935a) and Galaxiella (McDowall 1978b) still remain despite several changes to some of their contents, whereas Mesites (Jenyns 1842), Austrocobitis (Ogilby 1899), Querigalaxias (Whitley 1935), Lyragalaxias (Whitley 1935), Saxilaga (Scott 1936a) and Agalaxis (Scott 1966) have been rejected by various authors. The full details of the taxonomic history of the galaxiid group is a large work in itself and they are more fully outlined by Frankenberg (1969) McDowall (1970c) and Andrews (1976).

First records of the Tasmanian fauna start with the reference to Esox truttaceus apparently collected from Tasmania (Cuvier 1817). As McDowall (1967b) has pointed out this was a nomen nudum as the name was only "used as a footnote to the definition of the genus Galaxias."

G. truttaceus was later described by Valenciennes ( in: Cuvier and Valenciennes 1846) and Scott (1936a) described G. scopus from Clarke Island in the Bass Strait. However this species was later treated as a subspecies of G. truttaceus by Munro (1957b) and then as a synonym of

G. truttaceus by Stokell (1966), McDowall (1967b) and Andrews (1976).

Galaxias maculatus was first described by Jenyns (1842) as Mesites maculatus from material collected in South America. The first record of this species from Tasmania would appear to have been collected during the voyage of the "Erebus" and "Terror" (Richardson 1848) where the specimen was identified as G. scriba Cuvier and Valenciennes (1846).

The species was perhaps better known as G. attenuatus Jenyns in the Australian and New Zealand region until the work of Stokell (1966). He pointed out its synonomy with G. maculatus but used subspecific names to distinguish Australian, New Zealand and South American forms. This proposal was rejected by Scott (1968) and apparently ignored by Whitley (1969) who preferred the earlier genus Austrocobitis Ogilby. This genus had not been used by any other author other than Whitley since its original proposal by Ogilby (1899).

McDowall (1967b) rejected the use of trinomials and regarded all forms as G. maculatus and this name now appears to be generally accepted (Frankenberg 1974; Andrews 1976) although the subspecific names were used in some papers (Campos 1970; Pollard 1971b).

The first major work on Tasmanian icthyology was that of R.M. Johnston published in 1883. This work listed the previous two species and described G. auratus, G. weedoni and G. atkinsoni. The first of these three new species has remained unchanged in name with the only confusion being in relation to its type locality which was cleared up by Andrews (1976).

G. atkinsoni was soon listed as a synonym of G. weedoni

by Regan (1905) who also described G. affinis. Prior to this a mainland form had been described as G. coxii by Macleay '1881a) but this name was not used for the Tasmanian form until much later (Frankenberg 1967, 1969, 1974) although Mack (1936) thought G. affinis and G. coxii may have been conspecific.

After the description of G. parkeri by Scott (1936a) it was not until 1970 (McDowall 1970a) that the name G. brevipinnis was used for the Tasmanian species. He found G. weedoni and G. parkeri to be synonyms of G. brevipinnis and later, G. affinis and G. coxii were also shown to be synonyms of this species by Andrews (1976).

The Tasmanian mudfish G. cleaveri was first described from northern Tasmania by Scott (1934) who subsequently (Scott 1936a) proposed the separate genus Saxilaga for this species and another northern form S. anguilliformis. Scott later described a further related species (G. upcheri) from southern Tasmania (Scott 1942b) which he preferred to place in the genus Galaxias. These fish have only recently all been placed in the genus Galaxias, as G. cleaveri by Andrews (1976). They show a marked resemblance to the New Zealand genus Neochanna both morphologically and in their habitat.

Other species of Galaxias have been described, G. johnstoni (Scott 1936a), G. parvus and G. pedderensis (Frankenberg 1968), G. tanycephalus and G. fontanus (Fulton 1978a,b), but at the present they remain as first described.

The small galaxiid found in the north-eastern corner of Tasmania was tossed to and fro from Galaxias as it was first described (Mack 1936) to Brachygalaxias by various authors (Scott 1942b, 1966; Stokell 1954; Frankenberg 1966; McDowall

1973c; Andrews 1976). Subspecific definition was then made between the Australian mainland, Flinders Island and Tasmanian forms by Scott (1971b). This was recognised by Frankenberg (1974) but rejected by Andrews (1976) where all forms were returned to G. pusillus. In the most recent work McDowall (1978b) has removed the species to the new genus Galaxiella along with two Western Australian species for numerous reasons outlined in that paper.

The third genus of galaxiids present in Tasmania is Paragalaxias described by Scott (1935a). It remained monospecific until recently when two new species, P. eleotroides and P. mesotes, were described from Tasmanias Central Plateau (McDowall & Fulton 1978a). These authors also upheld the synonomy of P. shannonensis with P. dissimilis, which had been proposed earlier by Stokell (1950), and suggested that the type locality of P. dissimilis was probably incorrectly listed by Regan (1905).

Stokell (1950), Whitley (1960) and Andrews (1976) have published plates which they list as either P. dissimilis or P. shannonensis, however these are all definitely photographs of the new species P. eleotroides.

A fourth species in the genus, P. julianus was later found in lakes to the west of Great Lake and was also described by McDowall and Fulton (1978b).

At the latest count there are fifteen species in the family Galaxiidae present in Tasmania and, as many of them are confined to the one or only a few water bodies, it is possible that more species may still be undiscovered.

The first aplochitonid was described from South America

when Jenyns (1842) described Aplochiton zebra. Subsequently Prototroctes was described by Gunther (1864) and later Lovettia by McCulloch (1915) for the Tasmanian whitebait. Prototroctes was later removed to the separate family Prototroctidae by McDowall (1969) as he considered it to have strong affinities with Retropinna.

Aplochitonidae is represented in Tasmania by the monotypic genus Lovettia and Protctroctes maraena is the only member of the Prototroctidae present.

The first Retropinnid was described by Richardson (1848) as a species of Argentina and the genus Retropinna was later formed by Gill (1862). Since then a number of species have been described, particularly from New Zealand where diadromous and lacustrine populations occur. There then followed considerable disagreement as to the validity of the many species (Stokell 1941, 1969; Woods 1968b; McDowall 1970b, 1972a). Further revision of the entire family has been proposed by McDowall (1979). The only member of the Retropinnidae present in Tasmania is Retropinna tasmanica which was described by McCulloch (1920).

## 1.4 Distribution and Affinities

All of the eleven families of native freshwater fishes represented in Tasmania have their closest relatives in the southern hemisphere, but the only family restricted to Australia is the Gadopsidae.

The lamprey families Geotriidae and Mordaciidae are confined to the cool temperate regions of the southern hemisphere (Hardisty & Potter 1971). The first of these two families

contains the monospecific genus Geotria which outside Tasmania is found in southern Western Australia and south-eastern mainland Australia, New Zealand, Chile, Argentina and the Falkland and South Georgia Islands in the South Atlantic. Mordacia mordax only occurs in south-eastern Australia but two other species of Mordacia are found in the southern hemisphere. They are the non-parasitic species Mordacia praecox Potter, which is found in southern New South Wales and the South American species Mordacia lapicida (Gray).

These four species are the only representatives of the lampreys in the southern hemisphere. Their two families along with the northern hemisphere Petromyzonidae comprise the total compliment of the order Petromyzoniformes (Hardisty & Potter 1971). There are, however, about twenty seven species in the northern family.

The Anguillidae has a wide distribution throughout the world and is a very closely related group taxonomically, the short-finned species being especially hard to separate. Of the two Tasmanian species, Anguilla australis the short-finned eel, also occurs along the eastern coast of mainland Australia, New Zealand, Lord Howe and Norfolk Islands and New Caledonia. It is extrememly common in south eastern Australia but does not extend as far north as the long-finned spotted species A. reinhardtii. This species is found from north Queensland down the east coast of Australia (Schmidt 1928b) to the northern and eastern coasts of Tasmania (Sloane pers. comm.). It also occurs on Lord Howe Island and New Caledonia (Schmidt 1928b).

Two other short-finned species occur marginally in Australia (Schmidt 1928), A. obscura from the Pacific and

A. bicolor from the Indian Ocean. A long-finned but unspotted species (A. dieffenbachii Gray) is common in New Zealand (McDowall & Whittaker 1975) and long-finned species are also found in South Africa (Schmidt 1925).

Each of the three perciform families found in Tasmania are represented by a single species. The kuhliid fish Nannoperca australis is also present in south eastern mainland Australia where other closely related genera Nannatherina and Edelia occur (Frankenberg 1974). Edelia also occurs in Western Australia (Whitley 1960) and the predominantly marine genus, Kuhlia is widely distributed throughout the Pacific (Frankenberg 1974) and marginally enters freshwater in Queensland (Lake 1971).

The only freshwater representative of the Bovichthyidae is Pseudaphritis urvillii which is common in Tasmania and is also present in south eastern mainland Australia. Its closest relatives are three marine genera of the same family which inhabit the cold waters of the southern hemisphere (Frankenberg 1974). Gosline (1968) included it with the nototheniods along with the New Zealand torrent fish Cheimarrichthys forsteri (Haast), which is the only other member of the suborder found in freshwater.

The fourth perciform family, the Gadopsidae, is, as mentioned earlier, confined to the Australian region. Its only genus, Gadopsis, occurs only in the freshwaters of south-eastern Australia. Lake (1971) listed two species of Gadopsis probably in anticipation of the publication of the findings of Parrish who detailed two species in his M.Sc. thesis (Parrish 1966) but as yet this work has not been published.

The closest relatives of this species would probably be the blennioid or trachinoid fishes (Richardson 1848; Parrish 1966) which are all marine.

The major group of Tasmanian fishes, the sub-order Galaxioidei, compromising four families, is restricted to the southern hemisphere since the rejection of Galaxias indicus Day by McDowall (1973b). Within the southern cool temperate region the Galaxiidae have the widest distribution of the four families, being found in southern Australia, New Zealand, New Caledonia and the southern parts of South Africa and South America. Three of its six genera are present in Tasmania with Paragalaxias confined to the state. Tasmania shares the genus Galaxiella with south-eastern Australia (1 species), and southern Western Australia (2 species) (McDowall 1978b) and the major genus Galaxias with all the areas listed for the family. However there is a high degree of endemism within the group as only four of the fifteen Tasmanian species are found outside the State.

G. maculatus is found in south-eastern Australia, New Zealand and South America as well as many off-shore islands in these areas. G. brevipinnis is found in south-eastern Australia and New Zealand and G. truttaceus is found in south-eastern and south-western Australia. The latter two species also appear to be closely related to other Galaxias species in New Zealand and in South America (G. brevipinnis only). Galaxiella pusilla is present in south-eastern Australia and two closely related species are present in Western Australia.

An endemic Tasmanian species G. cleaveri is very

similar in appearance and habits to the New Zealand mudfishes of the genus Neochanna. Other endemic species G. pedderensis, G. johnstoni and G. fontanus show similarities with the mainland species G. olidus Gunther.

The three other galaxioid families found in Tasmania are each represented by a single species. All three (Aplochitonidae, Prototroctidae and Retropinnidae) are quite closely related and their taxonomic status has been very unstable (see Greenwood et al. 1966; McDowall 1969, 1971a, 1976c; Nelson 1972; Rosen 1974). The aplochitonid, Lovettia sealii is confined to Tasmania with its closest relatives being the two South American species of Aplochiton (McDowall 1971a). This is the full complement for the family. The Retropinnidae contains the two genera Stokellia Whitley and Retropinna Gill with a total of only four species, one confined to Tasmania (R. tasmanica) another to south-eastern Australia (R. semoni) and two in New Zealand (R. retropinna Richardson and S. anisodon Stokell), (McDowall 1979). Only two species of the Prototroctidae have been described, one from south-eastern Australia and Tasmania and the other from New Zealand. The latter species has not been collected since the mid 1920's (McDowall 1976c).

As mentioned above the familial relationships of these three groups as well as the Galaxiidae is a matter of conjecture (Bertin and Arambourg 1958; Gosline 1960; Greenwood et al. 1966; Weitzman 1967; McDowall 1969; Nelson 1972; Rosen 1974) hence the classification which I feel best fits the fishes as I know them has been used here. For more, and probably better informed details the above papers should be consulted.

## 1.5 Zoogeography and Evolution.

The former existence of a large southern continental land mass (Gondwanaland) from which the present southern continents have separated appears to be generally accepted in essence by most modern schools of thought. The existence of this land mass could explain the present day distribution of most of Tasmania's freshwater fish fauna. The dominant group in our fauna, the galaxioid fishes have a circum-southern hemisphere distribution as do the lampreys and such a distribution could be explained either by the existence of land bridges or by a dispersing continental land mass. However it could be explained by a more recent colonisation by salt tolerant forms of these fishes. Such forms occur in both the galaxioids and the lampreys.

The land bridge arguments as expounded for the Australian fauna by Macleay (1883), Gill (1893), Ogilby (1896), and Stokell (1950, 1953) and on a wider scale by Simpson (1941) appear to have been largely rejected in recent years in favour of either of the other two options mentioned above.

The main criticism of the continental drift theory for the explanation of southern freshwater fish distributions (Rosen 1974) is that it requires that the galaxioids and lampreys have had very slow evolutionary rates such that G. maculatus has remained as a single widespread species since the separation of Gonwanaland. Although this is probably true for the lampreys it seems unlikely when considering the active speciation evident within the

galaxiids (McDowall 1970; Andrews 1976; Fulton 1978a,b; McDowall & Fulton 1978a,b) and in variation exhibited by G. maculatus in particular (McDowall 1967a).

McDowall (1964b, 1966a, 1969, 1970c, 1973a) has been the major exponent of the dispersal by salt tolerant forms theory as the explanation for southern hemisphere fish distributions and this was generally supported by Frankenberg (1974) in his work on the Tasmanian fishes.

McDowall (1970c) considered that oceanic dispersal of G. truttaceus from Tasmania had given rise to three New Zealand species of Galaxias. He also thought that the G. maculatus populations of South America were a result of dispersal by salt tolerant forms of that species. This theory has also received criticism, particularly by Rosen (1974) who considered that there was no evidence that G. maculatus does or even could undertake the transoceanic migration required by McDowall's theory.

The dispersion of freshwater fishes via salt tolerant forms had received support on a wider scale before McDowall (Myers 1949, 1953) and the probability of chance dispersals resulting in colonisation was discussed by Darlington (1970).

The above arguments are concerned with the distribution of the galaxioids and the lampreys. The other components of the fauna, the eels and the perciform fishes, also require some mention.

The eels appear to be of tropical or sub-tropical origin (McDowall & Whittaker 1975) and their present distribution is satisfactorily explained by dispersal of

the larvae via ocean currents.

The Gadopsidae is the only family of fishes confined to the Australian region (Parrish 1966) and is a 'primary division' freshwater fish under the classification of Darlington (1957). This species, and probably also Nannoperca australis, appear to have evolved from marine ancestors in the southern Australian region and spread to Tasmania via land bridges across Bass Strait (Frankenberg 1974).

Parrish (1966) suggested that the Gadopsidae evolved from a marine trachinoid along the southern coast of Australia about the Middle Miocene. Once established as a freshwater fish its populations in Tasmania and Victoria have been isolated since the Pleistocene glaciations. Parrish (1966) considered that speciation had occurred between the Tasmanian and Victorian populations but his results have not been formally published.

It appears that the third perciform species, (Pseudaphritis urvillii), has moved into freshwater from south of Tasmania where most of its present relatives now are (Regan 1910), rather than from the Bass Strait region as proposed by Parrish (1966). Regan (1910) considered that this species may be a "relict form...dating from a time when the seas of Australia were colder."

The most recent widely accepted paper on teleostean classification is that of Greenwood et al. (1966). These authors acknowledge the major contributions to this subject of many early workers such as Gunther (1862, 1868), Cope (1871), Gill (1872, 1893), Woodward (1901), Boulenger (1904),

Jordan (1923), Regan (1929) and Berg (1940). It is proposed by Greenwood et al. (1966) that the teleostean fishes have arisen polyphyletically from diverse holostean stock. They recognise three divisions the first of which contains the eels and eel-like fishes and probably the herring like fishes. The second contains only the primitive Osteoglossiformes and Mormyriformes which are present only in northern Australia. The third division contains the majority of the world's freshwater fishes. The 'Salmonoids' are believed to be the most primitive of this group and it is through this lineage that the major freshwater fish groups are thought to have evolved (Greenwood et al. 1966).

The evolution of the lampreys appears to have taken place early in the process of vertebrate evolution but there is some dis-agreement on the origins of the group. The origins and fossil records of the lampreys are well covered by Bardack and Zangerl (1971).

The salmoniform fishes dominate both the native and introduced freshwater fish fauna of Tasmania. However the relationships of the families involved have been the subject of many papers (Gosline 1960; McDowall 1964b, 1969, 1970c, 1971a; Greenwood et al. 1966; Weitzman 1967; Nelson 1972; Rosen 1974). Possible evolutionary paths within this group are proposed by Rosen (1974) but due to the scarcity of fossil data on these fishes the arguments of the above authors will remain largely untestable. As the Salmoniformes is considered to have originated in freshwater (Greenwood et al. 1966; Rosen 1974) there are few fossils known. Fossil galaxiids

no different from the extant species G. brevipinnis have been found in New Zealand however, but little zoogeographic importance was placed on this find (McDowall 1976a).

There appears to have been very little active speciation within the families Prototroctidae, Retropinnidae and Aplochitonidae. Gosline (1960) and McDowall (1971a) considered that the grouping of the South American genus Aplochiton and the Tasmanian Lovettia was to some extent one of convenience in avoiding over-fragmentation rather than to convey a strict evolutionary relationship. If they are shown to have a common ancestry then I find it hard to agree with the idea of migration of salt tolerant forms as an explanation of their distribution (McDowall 1971a) as Lovettia is restricted to Tasmania only and does not even occur on the Bass Strait Islands. This is not to say that it may not have had a much wider distribution in the past. I think it is more likely that the similarities are probably a result of parallel or even convergent evolution from a galaxioid ancestor. It is noted that McDowall (1978b) has recently removed the apparent zoogeographic ties implied by having an Australian and South American species in the genus Brachygalaxias when he created a new genus (Galaxiella) for the Australian species. The species, although similar, do not substantiate the zoogeographic implications suggested by them being congeneric.

In contrast to the above mentioned galaxioid families the remaining family native to Australia, the Galaxiidae, has undergone considerable speciation particularly in Tasmania

and New Zealand. It appears likely that this family had its origins in the Tasmanian region (McDowall 1970c; McDowall & Whittaker 1975) and present day species have been assembled into species groups by Frankenberg (1969). It appears that these groups are largely derivatives of the present day species which have a salt tolerant stage in their life cycle. For instance it appears that two Tasmanian species have evolved as a result of landlocking of G. truttaceus. These are G. auratus (Frankenberg 1974; Andrews 1976) and G. tanycephalus (Fulton 1978a). McDowall (1970c) has suggested that three New Zealand species have evolved from a similar ancestor. G. brevipinnis also appears to be the likely ancestor of several New Zealand species (McDowall 1970c) and probably the Tasmanian G. fontanus (Fulton 1978b). However this latter species is also quite similar to the mainland G. olidus which Frankenberg (1969) grouped with the other Tasmanian species G. johnstoni, G. pedderensis and G. parvus.

The origins of the Paragalaxias species are something of a mystery as they have remained confined in a small area of Tasmania's central plateau although undergoing active speciation in that region. Andrews (1976) suggested that this may be due to the absence of large, high altitude, shallow lakes in other parts of south-eastern Australia. Because of the forward placement of the dorsal fin (over the pelvic fins) in this genus it is possible that it may be the ancestoral link between galaxiids and salmonids or aplochitonids by loss of the adipose fin (McDowall & Fulton 1978a).

The Tasmanian mudfish G. cleaveri does not have any close relatives in Tasmania but three very similar species in the genus Neochanna are found in New Zealand. Again this similarity may not be of great significance phylogenetically but may be a result of the specialised nature of the fishes. However a common ancestor with less specialised habits is not unlikely.

G. maculatus does not appear to be closely related to any other Tasmanian species but it has given rise to at least one new species in New Zealand (McDowall 1967a, 1972b). The remaining Tasmanian galaxiid, Galaxiella pusilla, appears to be predominantly a mainland species, along with the two Western Australian species in the genus (McDowall 1978b). It's restricted Tasmanian distribution (see later section) is most likely a result of a southern invasion similar to that postulated earlier for Gadopsis and Nannoperca.

# CHAPTER 2 THE LAMPREYS.

Where lampreys are referred to below the details are intended to apply to both the Tasmanian species. Details applying to only one of the species or northern hemisphere species will be acknowledged as such.

## 2.1 Geotria australis; (pouched lamprey) and Mordacia mordax ; (short-headed lamprey).

The lampreys are among the most primitive of the vertebrates and are strictly not true fish (see Scott 1939) although they are usually included in treatments of freshwater fishes. They are often mistaken for eels but they do not have the slimey coating of the eels nor the same jaws or paired fins. The juvenile stages of lampreys go largely unnoticed in freshwater because they inhabit the stream substrate.

### 2.1.1 Distribution within the State.

The most recent maps showing lamprey distribution in Tasmania are those of Frankenberg (1974). He states that both the species "have largely overlapping distributions in Tasmania." He also records unidentified lampreys from the Bass Strait Islands and from the Little Henty and Piemen Rivers on the west coast. I have collected lampreys from several other sites within the range shown by Frankenberg and also both species from several sites on the Gordon River and some of its tributaries hence confirming the presence of both species on the west coast where Frankenberg had question

marks on his maps. Further collectingwould probably establish their presence in most rivers of the state which are still accessible from the sea. Contrary to the opinion of Hubbs and Potter (1971) Geotria obviously does occur on the east coast of Tasmania.

2.1.2 Habitat.

The adult phase of both species is passed as a parasite in the sea whereas the juvenile non-parasitic stage is passed in freshwater (Maskell 1929; Potter 1970). It is only the freshwater habitat which is dealt with here; indeed, there is very little knowledge of any facet of the life of the marine phase of the Tasmanian species.

The preferred habitat of both species in freshwater is silty areas at the edges of rivers or in quiet eddies or backwaters of rivers (Maskell 1929; Potter 1970). The latter author found for M. mordax in New South Wales that there was a marked preference shown for fine silt by specimens under 50mm. in length. Further details on the analysis of the substrates as well as flow rates at this author's sample sites for M. mordax are given.

The silty areas at the waters edge are mentioned by both Maskell and Potter as being sites of high density for lampreys. This may be due to movement and consequent grouping there due to receding water level (Potter 1970) and/or selection of the site for its high level of organic material (Hardisty 1944).

Hardisty and Potter (1971) have summarised essential conditions of ammocoete habitat as "dependant on stream

gradients, which will in turn, determine the overall velocity of the current, the type of substrate particles that are deposited and also the accumulation of organic debris." This statement is supported by Potter's (1970) findings for M. mordax where he found that the number of ammocoetes present in the faster flowing regions was less than in the slower flowing regions although the former were larger in size.

Samples of lampreys collected by me from the Plenty River in southern Tasmania at various times throughout the year and over several years have contained both species in different stages of development and this was also found for M. mordax in Victoria (Potter 1970) which indicates that it is not necessary for ammocoetes to move to any great extent to complete the juvenile freshwater stage of their life cycle. However, from the findings of Potter (1970) it would appear that flooding has a major influence on their movement as it not only causes actual displacement of the lampreys, but also greatly disturbs their habitat and causes them to move to recolonise a suitable area.

The results of tagging experiments by Potter (1970) also indicated limited movement by ammocoetes with perhaps greatest movement during the summer months. Potter also suggests that other factors such as conditioning of the environment by ammocoetes may be important in recolonisation orientated movement.

### 2.1.3 Food and Feeding Behaviour.

There are naturally two distinctly different types of feeding exhibited by the lampreys because of their different

modes of life in fresh and salt waters. There is no published account of the diet of juvenile or adult G. australis or M. mordax and specific reference to their diet are probably inferred from work on the northern hemisphere species. Hardisty and Potter (1971) cite several works which show that diatoms and desmids are a major part of the larval lamprey diet in the northern hemisphere.

The lampreys are generally not parasitic during their breeding incursion into freshwater (Potter et al. 1968a; Frankenberg 1974) and the adults probably do not feed at all after their return from the sea (Maskell 1929).

2.1.4 Life History.

2.1.4.1 Growth of ammocoete stage.

The freshwater stage of the northern anadromous lampreys is considerably longer in duration than the parasitic marine stage (Hardisty & Potter 1971) and the same is probably true for the two Tasmanian species. Potter (1970) gives the duration of larval life for mainland M. mordax as three and a half years and this probably also applies to Tasmania. The duration of larval life for G. australis has not been detailed. Potter (1970) has given length-frequency distributions and graphs of growth rate for mainland M. mordax where he found, not unexpectantly, that growth was highest during the summer months. In the same paper he gives length-frequency data for two Tasmanian populations (Wye and North Esk Rivers) showing that metamorphosis takes place at approximately 105-110 mm for these populations, and generally at a greater length on the mainland. Strahan (1963) gives the length for metamorphosis

of M. mordax as up to 16cm and for G. australis up to 10cm. The latter figure is in agreement with Maskell (1929) who gave 10 cm as the average length for New Zealand G. australis but stated that he also found specimens metamorphosing at 8.7 cm in length. No Tasmanian data is available for G. australis

2.1.4.2 Growth of macropthalmia stage.

In this stage the lampreys undergo the most obvious changes in their external morphology (Hardisty & Potter 1971) with the appearance of the eyes possibly being the most noticeable difference, along with the modification of the gill openings and development of the oral disc and changes in pigmentation, the latter being most apparent in G. australis.

The transformation to the macropthalmia stage has been found to be well synchronised in its onset for M. mordax (Potter 1970) beginning at the end of February to early March for mainland populations and some two months earlier in the Tasmanian populations studied. Potter et al. (1968a) found that there was no sexual dimorphism apparent in macropthalmia and despite mean length differences for mainland and Tasmanian forms the body proportions of each population were similar. However changes in the proportional body length ratios of M. mordax, macropthalmia and adults, during subsequent growth are reported. (Potter 1970) showed that increase in length of M. mordax during this stage is partly attributable to the elongation of the preorbital region.

The transformation from ammocoete to macropthalmia would appear to last about three to four months for M. mordax and most specimens have migrated to the estuaries within about eight or nine months from the onset of metamorphosis in the

mainland population studied by Potter.. The macropthalmia stage is regarded as finished with the onset of parasitic feeding by the lampreys (Hardisty & Potter 1971).

2.1.4.3 Growth of adult stage.

It is in this stage that parasitic lampreys show their greatest growth rate. For G. australis and M. mordax there is an increase in length from approximately 10 and 11 cm. respectivel to about 47 and 33 cm respectively on return to freshwater (Strahan 1963). A sample of 76 specimens of M. mordax trapped whilst ascending a wier in the Plenty River in late November 1977 were all found to be of a similar length (mean 34.21 cm) (Fulton and Sloane unpublished). Further data from this fish trap suggests that the average size of G. australis at this stage is about 60 cm in the Plenty River, Tasmania.

Unfortunately there is very little information on the growth rate, feeding habits or movements of adult lampreys in the sea. There are few isolated records of lampreys on fishes, Potter et al. (1968) record M. mordax from some freshwater fishes in estuarine areas and from barracouta. I have seen the same species from barracouta in Tasmanian waters but little else is known of this stage in the life of either Tasmanian species. However Hardisty and Potter (1971) estimate that the average duration of this phase is approximately 18 months for M. mordax and probably a year longer for G. australis.

The lampreys once again come under notice on their return to freshwater where they are often seen and caught attempting to negotiate barriers in streams (Strahan 1964). They still have their distinctive blue colouring at this time

which is called the 'velasia stage' (Strahan 1963, 1964). After entry to freshwater the bright blue colour, still evident for some time, gives way to dull grey to brown colour in G. australis whereas M. mordax is still blue in colour. Considerable development and enlargement of the sucking disc particularly in G. australis then takes place (Stokell 1955; Strahan 1963, 1964). This development in G. australis occurs in the latter stages of its migration (saccifera stage) as also does the development of the strange gular pouch or sac below the throat in the males (Strahan 1964) which may also be present to a lesser extent in M. mordax (Potter & Strahan 1968). There are many other morphological, physiological and anatomical changes associated with maturation (Hardisty & Potter 1971) such as cessation feeding, changes in body proportions, fin morphology and dentition, degeneration of the gut and osmoregulatory and blood composition changes, to name but a few. The details are further outlined in Hardisty and Potter (1971) mainly for the northern hemisphere species but many of these factors have been noted for the southern species as well (see Maskell 1929; Strahan 1963, 1964; Potter & Strahan 1968).

At the time of entry into freshwater there is very little development of the gonads of G. australis (Maskell 1929). Marked development must, therefore, occur from then on at the expense of the other internal organs and body reserves before spawning takes place.

2.1.4.4 Breeding.

The breeding site, the precise breeding time or the breeding behaviour have not been documented for either G. australis or M. mordax.

From Potter (1970) we do have the time of spawning for M. mordax as between the beginning of August and the end of October and from Maskell (1929) spawning for G. australis in New Zealand may occur from January to May. Water temperature was given as "the decisive factor in determining the onset of spawning" for northern lampreys by Hardisty and Potter (1971), but no details for the southern species are available.

It is possible that the spawning site may be similar to that of the northern species ie. in shallow oval depressions built in a sand and gravel substrate in an area of the stream with appreciable current.

Behaviour during spawning is unknown but two authors (Maskell 1929; Ivanova-Berg 1968) have suggested that the gular pouch of G. australis may be used here for movement of stones during courtship.

Some details of the fecundity of M. mordax in New South Wales are given by Hughes and Potter (1969) who give a figure of approximately 200 eggs/g of body weight.

2.1.4.5 Migration of lampreys.

There are two major migrations during the life history of the lampreys. The first towards the end of the macropthalmia stage and the second marking the completion of the parasitic phase.

The first migration for M. mordax in New South Wales commences five to eight months after the commencement of metamorphosis and the amount of water flowing downstream has a major influence on this movement (Potter 1970; Hardisty & Potter 1971). Potter (1970) reports that "Once the macropthalmia start their downstream migration they are

commonly found burrowed in areas where there is an appreciable water flow, or where the substrate is subject to the influence of the main river." He further reports that this downstream movement is more a rheotactic response of the lamprey to water flow rather than a result of the scouring effect of flooding as appears the case with ammocoete movement. Potter found that there appeared to be correlation between water flow and the length of time spent in freshwater by M. mordax and that low water levels in late winter or spring may delay this migration. There is no data on the movement of G. australis although I have seen macropthalmia of this species passing down through the trout hatchery at the Salmon Ponds on the Plenty River in Tasmania over an extended period in spring and early summer.

The peak of the second migration takes place in spring to early summer for both species (Potter et al. 1968a; Frankenberg 1974).

At this time large numbers of lampreys move upstream to spawn and are sometimes seen trying to negotiate barriers in streams. It is at this time that most of the samples of lampreys are taken both for scientific work (Potter et al. 1968a) and for eating, (Best 1924a, 1929; Graham 1953; Strahan 1964). Both species appear to spend more time on their spawning migration than the northern hemisphere species (Hardisty and Potter (1971). Generally this migration takes place during darkness with the lampreys burrowing during the day. Hardisty and Potter (1971) remark that the avoidance response to light of M. mordax is very strong and that the dorsolateral position of the eyes in this species may be an adaption for their strong burrowing habit.

The stimulus which initiates the migratory behaviour in the Tasmanian species has not been determined.

2.1.5 Anatomy, Histology, Ultrastructure and Endocrinology.

A few papers have appeared which can be broadly classified into the above category, probably doing the authors considerable injustice in the process. The content of these is varied and naturally a coherent picture of such broad subjects could not be achieved, hence the reader is referred to these papers for more than the brief details given here.

The first anatomical work on larval G. australis is that of Maskell (1930, 1931) where details of the structure of the gut are given for this species. Strahan and Maclean (1969) examined the gut in M. mordax and later Barrington (1971) commented on the findings of both papers concluding that there was a significant variation in the gut structure of both species compared with northern hemisphere species. Strahan and Maclean (1969) also give details of the enzyme activity in the gut of larval M. mordax.

Henckel (1944) gives some detail of the structure of the eye and associated tissues for M. mordax, but anatomical structure having received the most attention would be the dentition probably because of its taxonomic importance. It has been studied by Maskell (1929), Strahan (1960), Potter and Strahan (1968), Potter et al. (1968a), Hubbs and Potter (1971) and Hardisty and Potter (1971) to name a few. Changes in other anatomical features with growth of the lampreys are also significant and these are further detailed in Hardisty and Potter (1971). Strahan (1960) compares some aspects of the

anatomy of the ammocoete and macrophthalmia stages of M. mordax and G. australis.

The ultrastructure and development of the gonads of the southern species has received some attention (Hughes & Potter 1969; Hardisty 1971). The chromosomes of Mordacia have been studied (Potter et al. 1968b; Robinson & Potter 1969) the diploid number for the two Australian species of this genus being 76 which is less than half that of the northern species (Potter & Robinson 1971). The chromosomes of G. australis have not been closely studied but the number is thought to be closer to the northern species than to Mordacia (Potter & Robinson 1971).

One structure which has received considerable attention is the pineal complex (Dendy 1907; Eddy and Strahan 1968, 1970; Eddy 1972). These structures are figured for the three families by Eddy (1972) who outlines some of the functions of the complex. She states that it is involved in hormonal regulation of the melanophores and also regulation of development in all three stages of the life cycle. Joss (1977) in further examination of the pineal complex in G. australis concluded that it is "a photoneuroendocrine transducer conveying diurnal information to other body tissues."

There are most likely other papers under this heading which I have not mentioned but which would be found somewhere within "The Biology of Lampreys" (Hardisty & Potter 1971, 1972).

2.1.6 Physiology.

Very little data on the physiology of the Australian lampreys exists. Potter (1970) suggested that some ammocoete mortality probably results from them being washed into salt water and not being able to withstand the change.

Temperature is linked to several other processes such as onset of metamorphosis (Potter et al. 1968a; Hardisty & Potter 1971) and also, possibly via the pineal complex to metamorphosis (Eddy 1972), but there are few details given for the southern species. The effect of light on metamorphosis is suggested as a possibility by Eddy (1972) and the lampreys are known to show photophobic responses (Hardisty & Potter 1971) via some receptor system.

Potter and Nicol (1968) have studied the haemoglobins of the Australian lampreys but this work was not commented on in Riggs (1971) section on haemoglobins.

2.1.7 Disease, Parasites and Natural Predation.

I have not seen any papers referring to parasites or diseases of lampreys in the Australian region. Graham (1953) records that a lamprey (G. australis) was ejected from the stomach of a ling caught in New Zealand waters. McNally (1957) lists M. mordax as one of the food items extracted from cormorant stomachs in Victoria and Williams (1954) lists lampreys among the diet of New Zealand cormorants. The latter reference would be to G. australis as it is the only lamprey found in New Zealand.

2.1.8 Competition

There are no published accounts of inter-specific

competition between lampreys and any other native or introduced freshwater fish and it is unlikely that any such competition would occur in freshwater in view of the lampreys specialised larval life and their non-feeding adult stage.

There is no specific information on the effects of dams or wiers on lamprey migration but this would appear to be their major danger. In December 1977 I saw many specimens of adult M. mordax dead on the rocks below the Trevallyn dam on the South Esk River, Tasmania obviously after abortive attempts to scale the barrier.

2.1.9 Use as Food.

The European lamprey has been considered a delicacy since the days of the Romans and is still considered as such in parts of Europe. There is no commercial fishery for lampreys in Australia but some recent European migrants particularly those from the Baltic region are known to collect the adults on their return to freshwater (Strahan 1964). The New Zealand Maori also collected the lamprey for food on their early upstream migration at which time Maskell (1929) reports they are in their best condition. Hector (1872), Phillips and Hodgkinson (1922), Best (1924a,1929) and Graham (1953) remark on the use of G. australis as food by the Maori people and Best describes methods used for catching them.

# CHAPTER 3 THE EELS

Contrary to the opinion of Woods (1963) NewZealand is not the only country with more than one species of freshwater eel. In fact, four species of Anguilla have been recorded from Australia and two of these are found in Tasmania. But unlike many of the Australian publications on the lampreys which deal with both species, the two major species of Australian eels have seldom been dealt with jointly. Most of the work has been concerned with the more abundant and commercially important short-finned species, A. australis. This species will be treated first with a separate treatment for A. reinhardtii Where eels are referred to below the details apply to A. australis in the section so headed or A. reinhardtii in the second section.

## 3.1 Anguilla australis (short-finned eel).

Anguilla australis is one of the most widespread and common native freshwater fishes in Tasmania. It was first described by Richardson in 1848 from specimens collected during the voyage of H.M.S. Erebus and Terror.

Although it is present in Tasmania in quantities sufficient for commercial harvesting it has not received any detailed study in this state to date.

### 3.1.1 Distribution within the State.

The most recent map showing the distribution of A. australis in Tasmania is that of Frankenberg (1974). There are huge gaps in this record, as Frankenberg points out, but unfortunately most of the additional records are unpublished.

A. australis is also present in the Gordon River system in the south west, the Huon and Derwent systems, and in fact, almost all the coastal rivers of the state, as well as many lakes and rivers further inland and islands of the Bass Strait. They don't appear to be present in the upper parts of the Central Plateau but may well have been there or still persist in low numbers. It is probable that damming of many of the states rivers for hydro-electric power generation has limited the access of eels to most of the central lakes.

3.1.2 Habitat.

The adult life of A. australis is passed in freshwater but spawning takes place in the sea and little is known of the eels until they reach the estuary when they have transformed into what is termed the glass-eel stage (Sinha & Jones 1975). Jellyman (1977b) reports that, "glass-eels are generally sedentary during their first year in freshwater" but he does not detail the habitat for the New Zealand species he studied. Cairns (1941), also on New Zealand species, notes that as soon as the glass-eels contacted freshwater they "saught cover in the lower reaches of the rivers lying buried in the mud". Glass-eels have been found sheltering under stones in the lower riffles of streams and in mud and silt in upper parts of estuaries during daylight hours in Tasmania (Sloane unpublished).

The "elvers", as they are known after pigmentation takes place, apparently remain in the lower reaches of streams for varying lengths of time (Jellyman 1977a, Cairns 1941). Hence the habitat of the elvers is probably as given above at least until their upstream migration. This is the dispersal stage

for eels and they then spread throughout any lakes and rivers in their path. The adult habitat of A. australis in New Zealand appears to differ from that in Tasmania, in that the Tasmanian form is more widespread throughout the rivers. In New Zealand it is found mainly in tidal waters of streams and rivers and also in coastal lakes (Cairns 1941). Cairns further comments that it appears to favour areas less susceptible to rapid temperature change. In an examination of habitat preferences of New Zealand A. australis 26 cm and less long, Jellyman (1977a) found that this species preferred the siltier and slower flowing areas of the stream he sampled. He also showed that there was an increase in size with distance upstream. McDowall (1975) states that, "Estuaries, coastal swamps, and lagoons are important habitats for the short-finned eel." McDowall et al. (1975a) state that "Where bottom rooted vegetation occurs short-finned eels are found amongst the plants during the day, roaming more widely at night, to feed. In lakes devoid of vegetation, the eels bury themselves in bottom mud."

Care must be taken in relating New Zealand data to the Tasmanian situation however, as A. australis is the only species present over most of the island whereas both New Zealand species are widespread and coexist in the same habitat. Relationships between the two Tasmanian species where they occur together have not been studied. From my experience A. australis is present as an adult in almost all situations in the large and small rivers of Tasmania in weedy muddy sections as well as in the rocky faster flowing sections, but actual habitat preferences of this species have not been

critically examined in Tasmania nor is there any detail on movement apart from during their major migrations. However, commercial eel fishermen do make use of the natural (probably feeding orientated) movement when using unbaited fyke nets to catch eels.

Cairns (1942b) thought that the male A. australis lived only in the brackish waters but this was later discounted by Woods (1964) and Burnet (1952a, 1969) in New Zealand and Sloane (1976) in Tasmania. There is also some controversy as to whether habitat and environment may determine the sex of eels (Cairns 1942b; Bertin 1956; Ord 1978). I prefer to think that if there is a difference in sex ratios from different areas then it is probably a difference in habitat preference between the sexes.

### 3.1.3 Food and Feeding Behaviour.

The only studies which eximine the food of A. australis in Tasmania in any detail are those of Sloane (1976) and Lake and Bennison (1977). Bennison (1975) also gives brief details of eel diet in the Coal River. Lake and Bennison (1977) give numbers of food items in the stomach of eels from the Coal River in 1974, 1975 and 1976 and the Jordon River in 1976. Sloane (1976) details the type of food and quantity from four sites on the Coal River and one on the Jordon River during summer 1976, and one site on the Coal River during winter of the same year. The food items consumed by eels were found to vary considerably between sites and with season. Similar results were also found by Cairns (1942a, 1950) and Burnet (1969a) for New Zealand eels hence the relevant papers should be consulted for the specific diet.

Sloane also examined the stomach contents of eels collected in each of four samples taken over a twenty four hour period at six hourly intervals. He found that there was some variation in their major food items between localities during summer, as was found by Cairns (1942a, 1950) and Kilner and Ackroyd (1978) for New Zealand A. australis. Burnet (1969a) thought there was a tendency for New Zealand eels to feed on the most readily available food item and these results are supported by Sloanes data as he also gives abundance details on the invertebrates in his sampling area. Cairns' (1942a) work shows that there is also a difference in diet related to size of eels. This has not been investigated in Tasmania, but was not found to be the case with British eels sampled by Sinha and Jones (1967).

Unfortunately many of the New Zealand papers on the food of eels have lumped details from both A. australis and A. dieffenbachii together (Hopkins 1965; Burnet 1969a; Cadwallader 1975b) thus rendering the information useless for Tasmanian purposes. It may also be clouding the issue somewhat as there is indication in Cairns (1942a) results that A. australis is not as great a predator of fish as the long-finned species. Sloane (1976) found A. australis to be virtually incapable of catching live shrimps in an aquarium but that it would readily take them if dead or disabled. The available data do not indicate that A. australis is a serious predator of trout at all but some of the less active native fish may be taken at times such as Pseudaphritis urvillii in the Derwent River Tasmania (Lynch 1967).

Most of the above details refer to feeding of eels in summer but observation in England (Sinha & Jones 1967, 1975)

Japan (Okada 1960) New Zealand (Cairns 1942a, 1950; Burnet 1952b; Hopkins 1965, 1970) and Tasmania (Sloane 1976) suggest that feeding may be strongly seasonal in eels and may stop altogether in winter. Woods (1964) gave 6°C as the lowest temperature for feeding in New Zealand eels and at temperatures of 5-6°C in the Coal River Tasmania Sloane (1976) found that all eels captured had empty stomachs. Sloane further supported these findings with laboratory work in which eels were kept in aquaria at 5, 15 and 20°C simultaneously. The eels did not feed at the lower temperature but did so readily at the two higher temperatures.

The feeding of eels is reported as being mainly nocturnal in New Zealand (Skryznski 1974) but Sloane's (1976) observations from four samples in the one day in Autumn 1976 indicated that feeding in this case was less during the night. However more work is required on this subject, as it is on other feeding related topics such as digestion rates and maintenance levels (Cairns 1942a; Burnet 1952b; Sinha & Jones 1967, 1975; Sloane 1976).

### 3.1.4 Life History.

As with the lampreys the life history of the eels may be divided into several stages, although perhaps the points of definition of each are not quite so clearly defined. Some authors use the terms referring to the early stages loosely but I will attempt to interpret their data and use it in the approprtiate stage as defined below.

Leptocephalus - Ribbon like, laterally flattened marine juvenile stage.

Glass eel - Unpigmented transparent 'eel' shaped juvenile stage upon entry into freshwater.

Elver - Small pigmented eels up to about 10-12 cm in length before and during major upstream migration in freshwater.

Adult eel - To include all specimens having passed through the other stages and including the "silver eel" stage which is the name often used for the adult downstream migratory phase.

3.1.4.1 Growth of the leptocephalus and glass eel stages.

There is little detailed knowledge of the leptocephalus stage for A. australis as it is passed in the sea. The often reproduced figure of the development of the leptocephalus stage of the European eel (Schmidt 1924) may well apply to the Australian species. In this, it is shown that the leptocephalus is at first laterally flattened and ribbon-like and increases in length occur up to a certain stage. On nearing the coastline of their intended adult habitat they begin to shorten in length and assume the rounded shape of the adult eel The only records of the leptocephalus stage of A. australis are given by Jesperson (1942).

Jellyman (1977b) thought that the metamorphosis to glass-eel was initiated in the New Zealand eels by decreasing water depth as they approach the coast and that the length of the post-metamorphic period varied with temperature and the distance off-shore of its onset. European eels undergo a considerable reduction in length at this stage and Jellyman (1977b) found that later arriving New Zealand glass-eels were generally shorter than those in the earliest runs. This he attributed to the later arrivals being in a more advanced stage of metamorphosis due to rising sea-surface temperatures.

He gives length, weight and condition factors for monthly samples of A. australis glass-eels. Obviously metamorphosis involves major morphological, physiological and behavioural changes (Jellyman 1977b) and according to Menzies (1936) physical deterioration of the European glass eel continues until they resume feeding in freshwater.

On arrival in freshwater the glass eels, as their name implies are transparent but pigmentation soon becomes apparent in A. australis irrespective of whether they are in fresh or salt water (Jellyman 1977b) although the rate was found to be modified by temperature and background colouration. Jellyman further considers that the stage of pigmentation could reflect the length of post-metamorphic sea life. A table of the development of pigmentation in the European glass-eel is given by Strubberg (1913) and New Zealand eels were found to conform to this pattern by Jellyman (1977)

The length of A. australis glass-eels on arrival in freshwater in New Zealand was given by McFarlane (1952) as averaging 6.15 cm in October and by Jellyman (1977b) as averaging 6.03 cm in 1971 and 6.13 cm in 1972. Cairns (1941) gives the average length for New Zealand short-finned eels as 5.7 cm in their first year in freshwater. Details of the length of Tasmanian glass-eels have not yet been published. The age of the glass eels was taken to be two years in their first summer in freshwater by Cairns (1941, 1950) and McFarlane (1952).

3.1.4.2 Growth of the elver stage.

The elver stage begins with the development of pigmentation and the commencement of freshwater feeding by the glass eel

stage. The stage is completed when the elvers make their upstream migration. In between these two stages is a period of 4-5 years (Cairns 1950) or up to 7 years (Jellyman 1977) for A. australis in New Zealand. The length of elvers of A. australis at time of migration is given as 10-12 cm (Cairns 1941) and Jellyman (1977a) gives several tables which record lengths of migrating elvers in New Zealand. He found considerable variation in the size of elvers at different localities and in particular that elvers were larger on average at upstream sites than those collected downstream on the same river. He concluded that; "In a large river system, several separate migrations may take place concurrently during summer, with waves of eels grouped approximately by size penetrating further upstream each year."

Cairns (1941) gives a table of growth of A. australis in New Zealand up to ten years of age and Jellyman (1977a) gives growth details of the same species up to four years of age. Jellyman also comments that the upstream migrations of eels cease when they are about 30 cm long which corresponds to about the end of their seventh year in freshwater from the table of Cairns (1941). There is obviously some confusion in the literature on the length of the elver stage. Cairns (1950) states that the young eels remain in the lower reaches of streams for 4 or 5 years after arriving as 2 year olds. Shortly after in the paper he states that they move upstream as 4-5 year olds. It is most likely that the upstream elver migration is done in stages as found by Jellyman (1977a) and that the elvers are progressively larger with distance upstream. Some evidence of this has been collected by Sloane (unpublished) in his study of the Tasmnian elver runs.

3.1.4.3. Growth of adult stage.

This stage can be taken to start after the cessation of the upstream migrations of the elvers and as given earlier this is at about 30 cm for New Zealand A. australis (Jellyman 1977a). Hence during their adult phase short-finned eels grow from this size to about 100 cm in length and some 3 kg in weight (Jellyman 1977c).

The growth of A. australis has been studied in some detail in New Zealand by Cairns (1941) and Burnet (1969c) but there is considerable disagreement between the two sets of results. As pointed out by Skrzynski (1974) Burnet's results are probably more reliable as he used individual tagging data to support his estimates from otolith reading. Burnet showed that New Zealand A. australis grow about 6cm/year at 20 cm in length decreasing to about 2cm/year at 60 cm, with no growth at all during winter. Burnet's results showed consistently lower growth rates than those of Cairns (1941). However the former authors tag data indicate considerable individual variability and between site differences also occur; hence he concludes that growth rates of the order of those obtained by Cairns are not unlikely.

In the only study on the growth of the eel in Tasmania Sloane (1976) obtained similar results to those of Burnet (1969c). Sloane also found considerable individual variability of growth rate but taken overall the growth rates were similar for all sites studied. Sloane gives graphs of otolith radius against fish length for samples from several sites showing that there is a highly significant linear correlation. He also gives graphs of log length against log weight which also show a strong linear correlation similar to that given by

Woods (1964) for New Zealand eels. Burnet (1969c) gives length-age curves for New Zealand A. australis up to 30 years of age, and Shorland and Russell (1948) also give length-weight relationships for the New Zealand eels. Length-frequency distribution over a twelve month period is given by Kilner and Ackroyd (1978) for New Zealand eels from an estuary.

Differences in the growth rate of male and female eels have been reported for European eels (Bertin 1965; Sinha & Jones 1975) as well as for A. australis in New Zealand (Burnet 1969b; Jellyman 1977c). Sloane (1976) found that this sexual difference also occurs in Tasmanian eels and he graphs age-length relationships from back calculation of otolith radius from male and female eels to illustrate this.

The age of A. australis at maturity appears somewhat variable. Castle (1972) stated for New Zealand eels that "at migration eels are probably not less than 12-15 years old and most migrants are no doubt appreciably older." Sloane (1976) recorded Tasmanian eels up to 10 years of age in his study and Burnet (1969b) gives details of New Zealand A. australis up to 30 years of age which is also the maximum age of short-finned females given by Jellyman (1977c). However, Cairns (1950) suggests that the larger female eels may be aberant forms which do not migrate but are sterile and probably die in freshwater.

The size of mature migrant A. australis in a New Zealand population was given by Hobbs (1947) as ranging from 38.1 to 58.4 cm for males with a mean of 48 cm and from 55.9 to 81.3 cm for females with a mean of 68.8 cm. Burnet (1969b) gives details of migrants from another New Zealand population

over six seasons and found similar results to those of Hobbs (males, range 33-58 cm, mean 43.4 cm females, range 53-81 cm, mean 64.1 cm). The sizes of migrant Tasmanian A. australis have not been investigated.

Yet another morphological change takes place when the eels undergo their migration to the sea. These changes were described for New Zealand short-finned eels by Hobbs (1947) as follows "Migrant S.F. eels were distinguishable by their greatly enlarged slightly pointed, black or black fringed pectoral fins, by enlargement of the eyes and reduction of the lips, and by the extension of reddish-black shades into the inside of the mouth. Usually sensory pores on the head were much more conspicuous on migrants. Copper and pale greenish shades tended usually to be replaced by grey." Other changes which accompany maturation are described by Cairns (1941).

3.1.4.4 Migration of eels.

Cairns (1950) states that "Three distinct migrations have been observed in New Zealand" and these migrations have also been recorded in Tasmania (Frankenberg 1974) but details have not been published.

The first migration which comes under notice is the invasion of estuaries by the glass-eels. The movement of the leptocephali from the breeding grounds to the coastline could also be considered as a major migration but records of specimens during this phase are rare and accurate data on stimuli for migration etc. are non-existent for Tasmanian eels. It is probable that this is a passive movement via ocean currents rather than an active migration.

The arrival of glass-eels in New Zealand has been studied

closely by Jellyman (1977b) who records that A. australis glass-eels arrive from July to December with a peak in September-October, however there is some indication that their arrival in Tasmanian estuaries may be some months earlier than this (Sloane unpublished).

Jellyman (1977b) records that "Glass-eels arrive in the mouth of the stream individually, swimming at or near the surface." i.e. no schooling behaviour is evident in early arriving glass-eels however as indicated by Jellyman and by Deelder (1958) for European eels the schooling habit develops shortly after arrival in the streams. Jellyman (1977b) further states that as the eels are responding individually to migratory stimuli they can be expected to show up any preferred time of invasion per night.

Jellyman examined the effects of various physical factors on the migration of glass-eels and although he pooled his results for both A. australis and A. dieffenbachii the information is useful in a study of the former species. He ruled out any influence on migration attributable to the lunar cycle or to rainfall. By the lunar cycle Jellyman is referring to any differences which may have been related to the spring and neap tide periods. The most positive migratory stimulus was found to be light (or lack of it) with migration only taking place during darkness with a peak between 2100 hr and 2200 hr and only 7% of the invasion after midnight. He did find a relationship to the tidal rhythm in that early season glass-eel invasion took place largely due to passive transport by flood tides whereas later in the season the eels move into freshwater largely against ebb tides. This seasonal difference

in the response of eels to flowing freshwater was further examined by Jellyman (1977b) in laboratory experiments. Similar behavioural responses were recorded for European eels by Deelder (1958) who related the response to a behavioural change which takes place in the eels after metamorphosis from the leptocephalus stage, ie the later season glass-eels are further advanced in this change and thus exhibit a positive attraction to flowing freshwater.

Water temperature may be involved to a lesser extent in this migration and Jellyman (1977b) considers that it could effect the time of onset of the invasion and its intensity.

The results of Jellyman (although they may be related to Tasmania as far as the species is concerned) would be very difficult to duplicate here due to the vastly different structure of streams in Tasmania and New Zealand as there is virtually no estuary as we know it in New Zealand streams.

Following the glass-eel invasion the next major migration of eels is that which constitutes the 'elver run'. This migration takes place in summer when small eels up to about 7 years of age (Jellyman 1977a) move upstream in extremely large numbers. This migration of A. australis takes place during late January and February in New Zealand (Cairns 1941, 1950; Jellyman 1977a) but again it appears earlier in Australia with large numbers of elvers moving upstream throughout December and January (Kershaw 1911; Sloane unpublished.). This movement is a well defined migration in New Zealand (Skrzynski 1974) and probably also in Tasmania but is usually only observed where some form of barrier obstructs the path of the eels.

Jellyman (1977a) states that, "the stimuli which initiate migration are unknown", but suggests that it may be a summation of factors including an increase in water temperature above a certain threshold level, increasing day length and sociability of eels. He does not regard increased water flow as a causative effect but suggests that it may be associated with peaks in the runs. There is no detailed documentation of the elver runs in Tasmania or mainland Australia. Kershaw (1911) and Hall (1905) note several sites where "eel fares" occurred in Victoria but although these runs are often well known locally they are rarely documented.

The climbing ability of the elvers is of major importance to the dispersal of eels and it appears that their weight may be an important limiting factor in relation to this climbing ability. Kershaw (1911) noted that the elvers never attempted to climb rocks washed by running water and he considered that they were probably unable to do so. Woods (1964) found that the smaller eels were more successful climbers and that their weight rather than length was of major importance due to surface tension effects. Woods found that the optimum size of A. australis for climbing difficult objects was 8.8 ($\pm$0.7)cms and 0.52 ($\pm$0.12)g. These results are supported by Jellyman (1977a) who also found that 8.8 cm was the mean length of a sample of elvers found climbing a vertical wall at the Karapiro Dam in New Zealand. He suggests that the maximum length for vertical climbing is probably 12 cm or a weight of about 2.5g. Jellyman (1977a) also gives details of the method of climbing of elvers and more details are given by Skead (1959) for South African elvers.

In New Zealand mature adults of A. australis commence their downstream migration to their marine spawning grounds during February and March (Cairns 1950; Burnet 1969b). The migration was found to be later for eels moving from Lake Ellesmere (New Zealand) into the sea by Hobbs (1947) probably due to the proximity of this lake to the sea. The timing of the migration has not been published for the Tasmanian eels but the data should soon be available with the commencement of commercial downstream trapping of eels in the State. Burnet (1969b) found that there was also a well defined downstream movement of immature A. australis (about 14 cm long) with the peak of this run preceding the mature eel run by about a month.

The runs of both mature and immature A. australis exhibited a lunar as well as seasonal periodicity (Burnet 1969b), and Hobbs (1947) found that the migrations took place almost entirely at night. Both migrant and immature specimens show minimum movement during the full moon with much greater movement occuring over more than half the rest of the lunar period. Burnet (1969b) also found that the larger runs were associated with higher rainfall and he concludes that "heavy rainfall (at the appropriate phase of the moon and in the correct season) stimulates the larger runs of eels." Burnet also indicates that weather systems may be involved in the timing of the larger runs but that water temperature does not appear to have any effect.

Burnet (1969b) does not record any difference in the timing of movement of male and female A. australis. Cairns (1941) stated that the males moved into the sea earlier than the females, however the latter author did not recognise any males from upstream at all.

Many of the amazing stories about eels stem from their habits at this stage of migration. They have often been reported moving overland across moist ground (Hall 1905; Kershaw 1911) and sometimes to their death across dry ground (Cairns 1941) in their endevour to reach their marine breeding grounds.

3.1.4.5. Breeding biology.

Nothing is known of the breeding habits of A. australis and the breeding site is not accurately known. This facet of the life history of eels has been associated with many legends and myths throughout history such as those quoted by Kershaw (1911) "that they breed in mud, or are generated from the skins of snakes or old eels, from slime, or from horsehairs." Most of these stories would be of European origin but the Maori have many legends surrounding the New Zealand eels (see Best 1902, 1924b; Hamilton 1908; Downes 1917). In particular the Maori mythe is that it was an eel and not a serpent which tempted the first woman (Phillipps 1925). Among the early New Zealand workers Duigan (1876) thought that it was not necessary for eels to go to sea at all to breed and Canavan (1892) thought that eels brought forth their young alive in the tidal waters and that both the adults and young go up the rivers again.

Archey (1923) considered that the west central Pacific was the only breeding site from which the ocean currents were such as to explain the distribution of A. australis. Schmidt (1925) suggested that the spawning grounds of A. australis are situated in one or more centres in the ocean near the tropics east of Australia. Cairns (1941) considered that his data for arrival time and locality of arrival of New Zealand glass-eels supported Schmidt's hypothesis and Castle (1963)

further defines the site as "well to the east of New Caledonia- that is, between Fiji and Tahiti." This area now appears to be generally accepted as the probable spawning site but further investigation is required. Castle (1963) wrote that only three leptocephali collected in the Pacific could be assigned to A. australis hence this phase of the life history is largely unknown and can only be assumed to be similar to that of the European eel, more details of which are given in Bertin (1956) Sinha and Jones (1975) and Moriarty (1978).

Todd (1976b) experimented with artificial maturation of A. australis kept in sea water in New Zealand. He used various hormones to induce maturation of the gonads of both males and females but although spawning did occur, fertilisation was not successful. He found that the maturation time was dependant on temperature with higher temperatures shortening the maturation time. The eggs of A. australis were 0.8 to 1.2 mm in diameter and pelagic (Todd 1976b) which is similar in size to other species of Anguilla (Fontaine et al. 1964; Yamauchi and Yamamoto 1974; Edel 1975). Hormones have been used in several studies on artificial maturation of the European eel (Boetius et al. 1962; Fontaine et al. 1964) and the American eel (Edel 1975; Ghittino et al. 1975) and a series of successfull studies have been made on artificial maturation and early development of the Japanese eel (Yamamoto et al. 1972; Yamamoto et al. 1974; Yamauchi & Yamamoto 1974; Yamamoto et al. 1975a; Yamamoto et al. 1975b) and it appears fromthese studies that it may be possible to bypass the need for a spawning migration at all.

3.1.5 Ultrastructure.

Todd (1976a) describes the ultrastructure of the spermatozoa and spermiogenesis of A. australis in New Zealand. He found the spermatozoa of this species to be similar in size and shape to those of the European and Japanese eels.

3.1.6 Physiology.

The oil content of eels has been investigated in New Zealand (Cunningham 1935; Shorland & Russel 1948; Shorland 1950) in relation to the vitamin contents available from such oils. Shorland (1950) in summary states that the oil content of immature eels increases with the length of the eel but that the distribution of oil in immature eels is quite different from that in the migrants. Shorland and Russel (1948) showed that just prior to migration there was a redistribution of oil from the tail region into the trunk and then to the head and ovary resulting in a more uniform distribution of oil. McFarlane (1950) briefly investigated the thiamine content of eels in New Zealand.

The haematology of New Zealand eels was investigated by McArthur (1977). One of his findings was that the glass eels and elvers had primitive blood cell types and probably lack the ability to resist pathogens such as the protozoan Ichthyophthirius multifiliis.

3.1.7 Diseases, Parasites and Natural Predation.

The study of diseases of A. australis is becoming much more urgent with the increasing demand for eels and consequent establishment of eel farms. Hine and Boustead (1974) produced " A guide to disease in eel farms" which gives the diseases

known from New Zealand eel farms. These authors indicate that once the glass- eels have been in freshwater systems they have become exposed to many of these diseases naturally. The fresh run glass-eels however are virtually free of any infection. It is most probable that all or some of these diseases could, or already do, occur in Tasmanian A. australis stocks .

Many parasites have been found on or in A. australis (Manter 1954; Hewitt & Hine 1972), the latter authors record five species of digenetic trematodes and four nematode species from various sites in A. australis. Another trematode species from various sites in A. australis is cited in Hine (1977d). A sporozoan (Hine 1975a) and three species of protozoan (Hine 1975b) are shown to be present in New Zealand specimens of this species. In the latter two papers Hine gives details of disease in eels related to infection with these parasites (especially for the sporozoan). In a later paper Hine (1978a) describes variation in the spores of the protozoan as well as variation in the site of infection.

McFarlane (1939, 1945, 1951, 1952) gives details of the life cycles of three trematode parasites using A. australis (and others) as a host. He gives details of the relationship of their life cycles to the biology of the eel in New Zealand streams. It is not known whether these trematodes, or any of the other parasites mentioned are present in Tasmanian eels. However the cercaria of one of these species (Coitocaecum anaspidis) was first described from the syncarid Anaspides tasmaniae in Tasmania, hence it may well be present in A. australis in this state (Hickman 1934).

A parasitic copepod is recorded from A. australis in New Zealand (Hewitt 1978) as is the glochidia of a mussel species (Hyridella sp.) (Hine 1978a). Other parasites of A. australis are recorded by Rid (1973), Martin (1974) and McArthur (1976). The distribution and frequency of occurrence of 26 species of parasites found in A. australis are discussed by Hine (1978a).

Falla and Stokell (1945) and Williams (1945) record Anguilla sp. from the stomachs of a number of specimens of the black shag Phalacocorax carbo in New Zealand. Mills (1965) showed that A. anguilla was often eaten by cormorants in Scotland and McNally (1957) lists A. australis as part of the diet of cormorants in Victoria.

It is probable that larger eels may be an important predator of smaller eels especially elvers. This has been shown for European eels by Sinha & Jones (1975) and Moriarty (1978). The latter author also states that the elvers are the subject of a variety of predators especially gulls during the daylight hours.

Predation upon eels has not been reported in Tasmania but they are probably subject to the same treatment reported above.

### 3.1.8 Competition.

It is easy enough to show that two fish species are using the same food items in their environment but much more difficult to show that they are actually competing for these items. Hence, competition between trout and eels has often been assumed without actually being proven (eg. Hobbs 1948; Lynch 1966). The studies of Sinha and Jones (1967, 1975) and Pritchett (1974) indicate that the European eel is not a serious

predator of trout and this was also found for A. australis in New Zealand (Cairns 1941, 1942a, 1950; Burnet 1952b, 1969a; Hopkins 1965; Cadwallader 1975b) and in Tasmania (Sloane 1976; Lake & Bennison 1977). Allen (1961) makes the point that "trout populations were established in the face of this predation" (speaking of eels) "and it seems unlikely that the predators will seriously menace their continued survival."

In the studies of the diets of eels in Tasmania mentioned above none of the authors were able to conclude that competition existed between eels and any other fish species present.

In further work on eel/trout relationships in New Zealand Burnet (1968) removed the eels from a section of stream. He studied the trout population for three years before and four years after such removal. After the eel removal there was a definite increase in the number of trout present but a decline in the growth rate and condition of the trout. Hence the eel / trout relationship before removal of the eels had been a beneficial one from the point of view of the trout anglers.

In another study of a small stream Burnet (1959) found that "the removal of a moderate eel population has no measurable effect on the trout population." Burnet (1969a) indicated that another river he studied was capable of carrying a larger crop of eels than trout because of their relative feeding habits. He also thought that competition was largely avoided by differences in preferred diet and feeding site. The feeding site of the eels was largely in the weedbeds whereas the trout were predominantly riffle feeders.

Although these recent works have largely exonerated the eel as being of great danger to trout many early workers thought otherwise and campaigns of eel destruction were undertaken in New Zealand. Cairns (1942b) reports on one of these but

no results of the program were given. Hobbs (1948) also considered the eels as a danger to trout and listed ways of excluding or eliminating them from trout streams. Once the adult eels are eliminated it appears that there is very little replacement by other adults (Cairns 1942b; Burnet 1969), hence the eel population of a stream could be drastically altered by such destruction or removal campaigns.

The indirect effects on eels of man's activities are also of considerable importance. McDowall (1977) indicates the dangers to free passage of eels in streams by forestry practices such as road construction in New Zealand. In another paper, (McDowall 1975) swamp reclamation and drainage are seen as a danger to an important habitat of A. australis in New Zealand. In a further paper (McDowall 1976b) the important role of the estuary in the life cycle of eels as well as other fishes is indicated. Kilner and Akroyd (1978) in their study of the Ahuriri estuary in New Zealand show that this area is of considerable importance to the short-finned eel. Therefore, there is a need for great care in man's use of the estuaries so that habitat changes and pollution may be minimal.

### 3.1.9. Use as food.

There is no documented evidence of the value of A. australis as a sport fishery throughout its known range but eels are certainly keenly sought for food by many people in Tasmania and elsewhere.

The Maori people have sought the eel for many years in New Zealand (Sherrin 1886) and accounts of their fishing devices and methods are given by Hamilton (1908), Downes (1917)

and Best (1924a). The Maori used an eel-wier or "tuna" similar in design to the modern downstream trap to capture migrant eels. Elvers were also collected at barriers to their upstream migration and a variety of nets, traps and spears were constructed and used for catching eels by the Maoris.

The short-finned eel is also the object of a valuable commercial fishery in Australia and New Zealand. This industry commenced in Tasmania about 1965 (Lynch 1977) and involves the use of usually unbaited fyke nets in lakes, swamps and ponds (Anon. 1968b). The New Zealand eel fishery showed a dramatic increase in production after about 1965 (Jellyman 1977c) until production exceeded 2000 tonnes in 1972. At this stage Castle (1972) expressed concern for the future of the eel industry in New Zealand and Waugh (1973) was concerned that over-exploitation of eels could adversely effect trout yield.

The peak of the eel industry was reached in Tasmania in 1968 with a production of 92,300 kg for the year (Lynch 1977) but since then it has undergone a decline in both the number of eel fishermen and the total catch. The progress of the eel fishery and development of eel fishing regulations in Tasmania is briefly dealt with in the reports of the Inland Fisheries Commission, Tasmania (Lynch 1967, 1968, 1969, 1970, 1972, 1973, 1977). In the report for 1970 the possibility of eel farming in Tasmania is indicated and in 1973 the first eel farm licence for Tasmania was granted. At this time the fishing for eels concentrated in the lakes and lagoons with eel fishing in the rivers being prohibited. Lynch (1977) indicated that the establishment of a fishery for migrating eels was desirable and legislation to allow such a fishery has since been passed.

The New Zealand eel fishery is an extremely valuable one to that country (Jellyman 1977c) and it appears to be better organised than the Tasmanian industry. At a seminar organised by the New Zealand Fishing Industry Board details of the catching techniques and legislative control of eel fishing and farming (Cunningham 1969) processing and marketing of eels (Tecklenberg 1969; Middleton 1969), and quality control requirements of the industry (Topp 1969), were given. Jellyman and Coates (1976) give details of the development of eel farming in New Zealand and its associated problems. Farming of eels began in 1971 but the ventures have failed to become fully established as yet. These authors outline problems confronting the industry and give details of farming trials in New Zealand. Jellyman and Coates indicate that some success has been had with fattening of wild eels of 400-500 g to get improved flavour and quality.

The sole Tasmanian eel farming venture has not been a success as such but the proprieters have turned to eel processing and the production of high quality products from eels and other seafood (Gray 1977). The smoked eel market is a very lucrative one (Lynch 1977) and one that could well be concentrated on in a state such as Tasmania where the total catch is small.

### 3.1.10 Future work.

The Tasmanian eels are at present being studied by the Tasmanian Inland Fisheries Commission and much needed information should come from this work. Research work is also underway on the biology of eels in Victoria and commercial aspects of the fishery in that state (Anon. 1977; Buckmaster 1977; Ord 1978).

Further work is also being carried out on the freshwater eels of New Zealand by Jellyman and Todd.

## 3.2. Anguilla reinhardtii; (long-finned eel)

In contrast to the short-finned eel (A. australis) the long-finned species has received little attention from authors. This probably is a result of the fact that it is less important commercially than the short-finned species.

In the section on A. australis much additional material on other anguillid species has been included where relevant. Much of this material could also relate to A. reinhardtii but it is not intended to repeat such data below. Hence the treatment of this species will be much briefer than for A. australis for this reason, and because of the limited data available on this species. The reader is therefore referred to the relevant section on A. australis for additional information.

### 3.2.1 Distribution within the State.

Frankenberg (1974) states that "the Tasmanian records of this species probably represent intermittent extentions southward of its normal range." He is referring to the reports of Scott (1953) and other unconfirmed reports of specimens from other north and east coast rivers. Scott (1934, 1935b, 1940, 1953) refers to several large specimens of A. reinhardtii from the North Esk and South Esk Rivers. Neither Johnston (1891) nor Schmidt (1928b) regarded the species as being present in Tasmania but in his 1883 paper Johnston states "some of the eels have been taken in the Ringarooma and South Esk Rivers over 30 lb in weight and over 20 in. in girth" and it is likely

that these may in fact have been long-finned specimens.

The fact that the presence of A. reinhardtii in Tasmania is not merely an "intermittent extention southward of its normal range" has recently been established (Sloane unpublished) as specimens of adult and glass-eel stage A. reinhardtii have been collected from several rivers on Tasmania's east coast. Commercial eel fishermen working the rivers of the north coast of Tasmania have provided reliable reports of the presence of the long-finned eels in some of these rivers and they have also provided some specimens.

Hence A. reinhardtii is firmly established in Tasmania and extends well down the east coast at least to the Carlton River and westwards along the north coast at least to the Tamar system and probably further.

3.2.2 Habitat.

There is no published information on the habitat of A. reinhardtii in Tasmania but some preliminary observations by Sloane (unpublished) suggest that it may prefer the lower reaches and estuaries of rivers where water flow is low. This differs from the habitat of the New Zealand long-finned eel (A. dieffenbachii) which apparently prefers to move further inland (Cairns 1941; Burnet 1969a).

Schmidt (1928b) refers to a letter he received from the Chief Inspector of Fisheries and Game, Melbourne regarding some specimens of A. reinhardtii, "these eels were taken in the eastern part of Victoria in brackish water, but are also commonly obtained in the rivers on that State 100 miles from the nearest salt water."

3.2.3. Food and Feeding Behaviour.

No detailed data has been published for this species, however Schmidt (1928b) quotes part of another letter he received regarding A. reinhardtii in Victoria a small part of which is quoted below, "I have seen them pulling my ducks under water". This would naturally need to be large examples of the species and I don't imagine that ducks would be their major food item, however the species is almost certainly an active predator of other fish as are the larger specimens of A. dieffenbachii in New Zealand (Cairns 1942a; Burnet 1952b).

3.2.4 Life History.

It is not necessary to divide the treatment of the life history of A. reinhardtii into separate sections as so little is known of any of the stages that it can easily be covered in one section.

The leptocephalus of A. reinhardtii has not been seen and published records of the glass-eel stage are rare. Schmidt (1928b) refers to a sample of "eel young" from the Richmond River, northern New South Wales which measured 49-54 mm. There is no date given with this sample nor does Schmidt say if they were in fact true glass-eels. Marshall (1928) recorded an "elver" of A. reinhardtii from near Brisbane which measured 54 mm and was collected in early February.

From his investigation of Tasmanian eels Sloane (unpublished) has found long-finned glass-eels in several Tasmanian streams. It appears from Sloane's data that they may be entering these streams considerably earlier in the year than A. australis (Feb-May c.f. Mar-Oct) and that they are shorter in length

than short-finned glass-eels (about 49 mm c.f. 57 mm for A. australis).

The upstream migration of elvers of A. reinhardtii was reported by Whitley (1929b) from the Parramatta River in New South Wales. The "eel-fare" began in late afternoon on Febrary 15 and most of the migration was at night. The migration continued until Februany 22 when it suddenly ceased. It recommenced on March 19 and continued until at least April 29 when the observations were ceased. The habit of forming their body into an S whilst climbing (Whitley 1929b) shown by this species is similar to observations on other species outlined in the previous section.

The growth rate of this species is unknown but the end result is a very large eel. Scott (1940) gives details of long-finned eels from four sites on the South Esk River measuring 1635, 1525, 1531 and 1658 mm and weighing 15, 13, 19, and 15 kg respectively. He later (Scott 1953) records a large specimen from the North Esk river which measured 1671 mm and weighed 18 kg. The Queen Victoria Museum, Launceston now has a specimen from south east Flinders Island which is 1400 mm long and weighs approximately 9 kg and Sloane has collected large specimens up to 9 kg from the Meredith River on Tasmanias east coast.

There are no published details on diseases and the only parasite recorded was a nematode from the swim bladder of A. reinhardtii collected near Sydney. Competition between this species and any other native or introduced fish has not been reported. Whitley (1929b) mentions that young of this species were eaten by kingfishers in the Paramatta River, New South Wales during the elver migration and that larger eels feed

upon them but no further details were given.

There is no data on their use as a sport fish but they are not favoured commercially although they are sometimes included in the Tasmanian catch.

# CHAPTER 4 PERCIFORM FISHES.

The three species of fish in this group are the "odds and ends"of a salmoniform dominated fauna. Two of the species are found only in freshwater (blackfish and pygmy perch) whilst the third (sandy) can move between freshwater and the sea with apparent ease.

The three species are only remotely related and show no superficial resemblance to each other. The blackfish and the sandy do not have any close relatives in freshwater in Australia but other pygmy perch species are present in south-eastern Australia. Each of the species are quite common within their respective ranges and could conceivably all be collected from the one site in northern Tasmania.

## 4.1 Pseudaphritis urvillii; (the freshwater flathead or sandy)

This species has been given a large variety of common names among which are: sandy, freshwater flathead, tupong, roach, pyke, congolli, marble fish and sand trout. It is one of the most common of the Tasmanian native fish and also one of the larger ones.

The species was first described from Port Jackson by Cuvier and Valenciennes (1831) as Aphritis urvillii and later given the generic name Pseudaphritis by Castlenau (1872). The best description of the species would probably still be that of Castlenau (1872) (for P. bassii).

### 4.1.1 Distribution within the State.

Frankenberg (1974) states that "Pseudaphritis urvilli is a widely distributed species probably occurring in most

Tasmanian streams-but usually less than 70 km from the sea." His distribution map shows that the species is present in streams all around the state and on Flinders and Maria Islands. Many of the streams not marked on Frankenberg's map also contain sandies but records of these have not been published. I do not know of any landlocked or lacustrine populations of this species in Tasmania as reported by Hall (1916) from Lake Purumbete in Victoria.

4.1.2 Habitat.

As stated above Frankenberg (1974) considered that P. urvillii is usually found less than 70 km from the sea but Lake (1971) records that the fish has been recorded some 400 km from the sea in the Snowy River. Frankenberg further states that the species is euryhaline. Johnston (1883) wrote that the sandy was "common in the lower waters of fresh-water streams near to the sea." It is recorded from salt water by Hall (1899), Waite (1923) and Kershaw (1928) and from inland saline waters in Victoria (Hall 1916). Pollard (1969) states that the "fish is equally at home in the river or sea. It can be transferred directly from salt to fresh water apparently without suffering in any way from the sudden change." There is some indication that only, or predominantly females inhabit freshwater (Lake 1971; Sloane 1976) and that the males are largely estuarine; however, this requires further study.

The specific habitat within this area has received little attention. Lake and Bennison (1977) stated that P. urvillii was collected "from sections with a gravel substrate and a moderate current flow." Sloane (1976) observed that they were collected from amongst logs and weeds in pools and also from weeded areas in faster flowing sections.

Sloane (1976, 1978) gives some indication of the abundance of P. urvillii within a site as he gives density and biomass levels for sandies in the Jordan River. The values were 0.001 and 0.03 fish/$m^2$ at two sites with biomass values of 0.03 and 3.58 g/$m^2$. The totals for the sites for all fish were 0.03 and 0.33 fish/$m^2$ and 0.33 and 20.9 g/$m^2$.

4.1.3 Food and Feeding Behaviour.

The only detailed study relating to food of the sandy is that of Sloane (1976). He analysed the gut contents of sandies during summer and autumn in the Jordan River. In each case the amphipods Paracalliope and Austrochiltonia formed the major part of their diet. Trichopteran larvae were also of some importance in both samples as were fish in the summer sample and dipteran larvae in the autumn sample. Electivity indices are given for the various food items in the diet of the sandy. These indicate that the sandy is actively seeking certain groups of Trichoptera in particular in preference to other food items available in pool and riffle situations. However the use of electivity indices is of questionable value in the absence of accurate data on feeding habits and invertebrate abundance.

In his autumn sample Sloane collected fish at four different times throughout a twenty hour period. The diet did not show any marked changes except that the trichopterans only appeared in the dusk and dawn samples. This could probably be attributed to their presence in the drift fauna at these times.

Lake and Bennison (1977) examined the stomach contents of only four specimens from the Jordan River. They concluded that P. urvillii was, "carnivorous with trichopteran larvae, Paratya tasmaniensis amphipods and gastropods forming the major part of the diet." Sloane concluded that P. urvilli was "an efficient predator capable of devouring comparatively large prey" (several galaxiids were found in sample stomachs; one stomach contained a small eel).

4.1.4 Life History.

4.1.4.1 Growth and age.

Sloane (1976) made some preliminary observations on growth of P. urvillii in aquaria. He kept sandies at each of three temperatures 5, 15 and 20°C. The fish did not feed at all at 5°C and probably do not do so in the field as water temperatures regularly drop below this level in many Tasmanian rivers during winter.

At 15 and 20°C the fish accepted food readily and Sloane found that "in both the sandy and the eel, the maximum food consumption and food utilization for growth recorded at 15°C differed markedly from those observed at 20°C.

When the food ration was unrestricted, both species consumed less food at 20°C than at 15°C and both utilized all rations of food for growth with higher gross efficiencies at the lower temperature." Thus at the higher temperature less food was eaten and the conversion efficiency of the fish was lower than at the lower temperature. Although these results are probably quite valid they are based on small sample numbers and would require further study.

Sloane (1976) calculated maintenance coefficients for the sandy and after comparison with those calculated by other workers for various fish species he concluded that the low levels were consistent with his field and aquarium observations that the sandy is relatively inactive.

Lake (1971) records that the species grows to a length of about 35 cm. Whitley (1960) states that it reaches 36 cm which is a realistic figure for Tasmania. However Whitley also stated that the sandy is nearly 11.4 cm long after one year, 16 cm at two years and 24.1 cm at three years. He also recorded a 27.3 cm species weighing 170 g. These length for age values are not supported by the findings of Sloane (1976). In his study Sloane first established that there was a highly significant linear correlation between scale radius and fish length for sandies collected in March and May of 1976 from the Jordan River. He then graphed mean length for age from back calculated data. The mean lengths for the first six years of life of the sandy as calculated by Sloane (1976) were 4.2, 8.8, 12.4, 18.4 and 21.2 cm respectively and these figures seem more appropriate than those of Whitley quoted above.

Sloane only found sandies from two to six years of age in his samples and all of them were female fish, however all age groups were approximately equally represented in number.

4.1.4.2 Migrations and breeding biology.

After considering the data above Sloane (1976) speculated on the life cycle of P. urvilli. He thought that the fish probably spawned in the estuaries or in the sea. Thus the female fish migrate to this region when mature and later the young female fish move up into freshwater in their second or third year. Sloane considered that the abrupt reduction in

numbers after age six suggested that the females migrate to spawn at this age and do not return. Downstream migrations of P. urvillii have been observed in the Murray River Victoria, in June, July and August. I feel that it is unlikely that such a fish would only mature once and not survive spawning.

A study underway at present on this fish indicates that some male fish do occur in freshwater but they are more common in the estuarine areas (Hortle unpublished). Future work in this study should provide valuable details on the life cycle of this species.

Although there is no concrete evidence to show where the sandies actually breed, the weight of opinion suggests that they do so in the estuaries or the sea. The breeding behaviour has not been observed, nor has the actual breeding site.

4.1.5 Diseases, Parasites and Natural Predation.

No diseases have been recorded for P.urvillii although it is often attacked by fungus in aquaria (as are most freshwater fishes). Johnston and Mawson (1940, 1947) record several species of nematodes from P. urvillii. These species are Eustrongylides gadopsis (= E. galaxias), Procamallanus murrayensis, Ascarophis murrayensis, Rhabdochona jaenschi, Spinitectus sp, and larvae of a species of Contracaecum. The authors do not list any ill effects on the fish attributable to these parasites.

Crowcroft (1944) records the trematode species Coitocaecum parvum from P. urvillii collected from Risdon near Hobart. Again there is no indication that the parasite has any detrimental effect on the fish.

There is no information to suggest that P. urvillii is the major object of any natural predators. However, there are a few reports that indicate it is occasionally taken by other fish species. Johnston and Mawson (1940) found P. urvillii in the stomach of a murray cod taken at Tailem Bend and Lynch (1967) found that sandies were taken quite often by eels in the Derwent River, Tasmania.

4.1.6 Competition.

Lake and Bennison (1977) indicate that trout, perch, eels, tench and freshwater flathead share common food resources but they do not specifically indicate that competition occurs between P. urvillii and any of the other species.

In his more detailed study of these fishes in the Coal River and Jordan River, Sloane (1976) found that there was sufficient similarity in the diet and feeding areas of the trout, perch and sandy where they coexisted to suggest that direct competition would result.

However, the study would need to be considerably extended before competition to the detriment of one or other species could be proven.

Whitley (1955) recorded that P. urvillii was "becoming rare in southern Australia and Tasmania" and he indicated that it, along with other species, should be given the utmost protection. Pollard (1969) also thought that "River works, pollution and the competiton of introduced species are combining to exterminate the congolli, which once had an extensive range. It is now almost unknown in New South Wales." However I doubt if these practices pose a serious threat to the sandy populations of Tasmania at present.

4.1.7. Use as Food.

There does not appear to have been any extensive fishery of any type for sandies. It is described in Pollard (1969) as "a fairly well flavoured table fish." I well remember fishing for it in the 1950's with worms as bait and frying the resultant catch.

4.2 Nannoperca australis; (pygmy perch).

One of the more colourful of Tasmanias native freshwater fish, the pygmy perch also makes a fine aquarium fish. The species was first described by Gunther (1861) from the Murray River. Johnston (1883) described it as Microperca tasmaniae without reference to Gunthers description. The name Nannoperca australis is now in general use in Tasmania but usually with the subspecific attachments given by Scott (1971a). As mentioned earlier such differences are not recognised in this work.

Recent descriptions of the species are contained in Munro (1961) and Scott (1971a) but most of the limited data on the biology of the species comes from the work of Llewellyn (1971, 1974) on the mainland populations of N. australis.

4.2.1 Distribution within the State.

As shown by Frankenberg (1974) the pygmy perch is found in most river systems along the northern coast of Tasmania and on Flinders and King Islands. The species is quite common throughout much of its range. It does not appear to have been transferred outside its natural range in the state despite the fact that it is often kept in aquaria in the south.

Johnston did report that it was transferred from the South Esk to some "local pools" (in Seal et al. 1883). Whitley (1972) reports that N. australis was recorded from "rains" of fishes in Gippsland, Victoria, but this method of dispersal has not been recorded for the fish in Tasmania.

4.2.2 Habitat.

Llewellyn (1974) reports that "Southern pygmy perch are commonly found in weedy and generally slow-flowing bodies of water, such as lakes, irrigation channels, billabongs and dams situated close to the main rivers..." Llewellyn was referring to inland Victoria and New South Wales populations of N. australis but the details suffice in describing the Tasmanian habitat as well. Johnston (1883), referring to pygmy perch in the South and North Esk Rivers, stated that "the young are found in large numbers in the shallow lagoons having connection with the rivers during some portion of the year." Further on the nature of the habitat of N. australis, Frankenberg (1974) found that this species is one of only three Tasmanian species "adapted to quiet, restricted waters of a permanent nature."

4.2.3 Food and Feeding Behaviour.

No details are available on this subject from natural populations. Llewellyn (1974) fed captive populations on Daphnia sp. and insect larvae.

4.2.4 Life History.

Llewellyn's (1974) study of the life history of N. australis largely relates to spawning and early development with brief details only on adult growth.

4.2.4.1. Growth and age.

Llewellyn (1974) found that after $2\frac{1}{2}$ months the pygmy perch is fully scaled and at this stage it is about 11.5 mm in length. They grow to an average length of 19 mm by the start of their first winter (about 5 months) by which time dorsal pigmentation begins to resemble that of adult fish. Llewellyn gives length frequency data for a breeding population from a pond at the Narrandera Inland Fisheries Research Station. The fish were all collected on the 9th April 1969 and Llewellyn gave their age as 6, 18 and 30 months with mean lengths for each group of 30, 38 and 47mm respectively. These lengths would appear to imply that the fish grow approximately 11 mm in one month and only 8 mm in the next 12 months. However Llewellyn is using data from both wild and captive populations and some differences in the growth rates of these populations at certain stages are apparent from his data

Whereas the captive pond population was predominantly in the youngest age group Llewellyn (1974) found that the wild riverine population he sampled was comprised largely of 1+ year class fish. There did not appear to be any difference in the growth rates of these two populations and Llewellyn indicated that growth either ceased or was minimal during winter.

Llewellyn recorded a female N. australis 82 mm in length and 7.21 g weight. His specimens from the Murrumbidgee River were up to 63 mm in length and 3.48 g in weight (females) and 56 mm and 2.25 g (males). He found that females were generally larger than males of the same age. Numerous authors record the species up to 3 inches or 76 mm (Castelnau 1872; Seal et al.

1883; Macleay 1885; Waite 1923; Whitley 1929a, 1960; Munro 1961; Lake 1959.) Johnston (1883) records the species up to 89 mm and Macleay (1885) gives the unlikely length of $5\frac{1}{2}$ inches or 140 mm. This may be a printing error as the rest of the text in Macleay's paper is quoted direct from Johnston (1883) who gives the length as 3 to $3\frac{1}{2}$ inches.

From Llewellyns (1974) tables on biological data on the pygmy perch one can extract length weight data for various lengths of both male and female fish. These data are all for fish taken approaching the breeding time hence the weights are higher than in non breeding fish.

4.2.4.2 Sexual dimorphism.

The most marked sexual dimorphism in the pygmy perch is evident in their colouration especially approaching and during the breeding season. At this time the males have bright red dorsal, caudal and anal fins. Black edgings also appear on the dorsal anal and pelvic (not pectoral as stated by Llewellyn 1971, 1974) fins as well as on the dorsal and ventral edges of the caudal peduncle and around the vent (Llewellyn 1974). It was found that some female fish may darken slightly but never to the same extent as the males. Dark brown to black spots along the sides are also more prominent in the males and become increasingly so with the approach of the breeding season. These spots are seldom found in young or immature fish up to 15 mm in length (Llewellyn 1971, 1974).

Llewellyn (1974) also found that as well as differences in pigmentation around the vent in this species there is also an anatomical difference. The female develops quite a large urinogenital papillae whereas a similar organ in the male is quite small.

4.2.4.3. Maturation and fecundity.

Llewellyn (1974) did not monitor the maturation of N. australis on a regular basis. However he showed that the percentage gonosomatic index of ovaries increased from a mean value for August of 5.1 to 9.4 in October (2.8 and 3.8 respectivel for testes).

Llewellyn observed that males began to show their breeding colouration in early June and the females "started to become more rotund." Temperature was 9.5 C at this stage. He found that females could be forcibly stripped of eggs by August 10 when the temperature had reached 14°C.

Llewellyn (1974) found that the mature ovaries and testes of N. australis are unequal in size with the left ovary being slightly the larger. He also found, not unexpectantly that fecundity is related to both length and weight of fish but with a considerable variation exhibited by similar sized specimens. He found that egg numbers varied between 506 and 4217 for fish 40 mm and 63 mm in length and 0.86 g and 3.49 g in weight. He concluded that there was a decline in fecundity in fish above 51 mm length and 2.80 g weight but his graphs of length/fecundity and weight/fecundity although suggesting such a relationship are not conclusive.

4.2.4.4 Breeding biology.

Llewellyn (1971) wrote that, "The species spawns randomly over a prolonged period while swimming. The eggs sink and become well dispersed over the bottom of the pond. Breeding has occurred only in small ponds at temperatures of 16°C and 21°C." In a later paper Llewellyn (1974) the temperature requirements for breeding are further defined.

Llewellyn found that the eggs were randomly scattered over the pond suggesting that each fish spawned intermittently over some time or that there was no close synchrony in the spawning of each female.

The actual breeding behaviour and spawning of N. australis has not been observed. However details of this have been noted for a closely related Western Australian pygmy perch N. vittata (= Edelia vittata) and they are described by Shipway (1949). Llewellyn (1974) compares details of spawning and development of N. australis and E. vittata. Llewellyn (1974) suggested that Since he only captured young wild fish in "heavily weeded, slow flowing bodies of water" then this type of area is probably the normal breeding and nursery site.

4.2.4.5 Embryology and development.

Details of the eggs and their development are summarised by Llewellyn (1974) as follows "The eggs were demersal, transparent spherical, telolecithal and essentially non-adhesive; possessed a cluster of oil globules; varied from 1.16 mm to 1.35 mm in diameter; and were scattered randomly during spawning. They hatched after between 2 days 18 hours and 3 days 7 hours at temperatures fluctuating between 15.8°C and 25.3°C." In this paper Llewellyn describes the development of the egg as seen in the laboratory and gives a series of 36 plates following this development through to hatching.

Llewellyn (1974) found that at hatching the larvae are 3.2 to 4.3 mm in length. Numerous oil globules are present at the anterior end of the yolk sac. These coalesce after about two to four days and the yolk sac is completely resorbed at about nine days.

The larvae are able to swim quite rapidly after about 6 hours and the swim bladder first appears at about 1½ days

after hatching.

The mouth first appears at about 4 days and the jaw structure and pectoral fins were apparent by the end of the fifth day. Llewellyn (1974) found that the end of the larval stage was signified by the change fromendogenous to exogenous feeding marked by the appearance of green pigmentation in the gut caused by browsing on algae. This occurred at approximately 6 days after hatching.

Further more detailed data on development of eggs and larvae are contained in Llewellyn (1971, 1974).

4.2.5 Diseases, Parasites and Natural Predation.

No accounts of diseases of N. australis have been seen. It is quite susceptible to fungal infection after transfer to aquaria, as are most freshwater fishes.

The nematode species Goezia fluviatilis, and species of Contracaecum and Ascarophis are recorded from N. australis from South Australia (Johnston & Mawson 1940, 1947). No details of diseases or debility (if any exist) associated with the infections are given.

Whitley (1929a) in his study of the notes of R.M. Johnston remarked that the young of N. australis were "frequently found dead when the brackish water lagoons of the North and South Esk are beginning to dry up in summer." Doubtless this is a result of the problems associated with falling water levels and rising temperatures and not some unknown disease.

Llewellyn (1971) regards N. australis as a forage fish in the Murray-Darling system and Whitley (1960) states that they have been used as forage for introduced and "farmed" fishes.

However these authors do not record which species in particular utilise them as food in the wild, nor do any other authors.

4.2.6 Uses.

The pygmy perch is obviously too small to provide any prospects for anglers. Johnston (1883) did remark "I do not think them good for food" but he did not mention whether he had tried them.

Some authors (Waite 1923; Whitley 1960; Scott 1962; Scott et al. 1974) indicate that it is an excellent aquarium fish and it is kept as such by enthusiasts in Tasmnia.

4.3 Gadopsis marmoratus; (river blackfish)

The blackfish is one of the better known native fish in Tasmania and on the mainland where it is also widely known as "slippery". It was first described in 1848 from a single dried skin (Richardson 1848). The first record from Tasmania is probably that of Gunther (1862). Further records and details are given by Johnston (1883), Seal et al. (1883) and Ogilby (1913) and more recently by Parrish (1966) and Frankenberg (1974).

As explained in the taxonomy section the Tasmanian blackfish may be a separate species (see Parrish1966) but a formal publication of the description has not appeared. Hence details of the biology of the mainland form must be taken as applying to the Tasmanian form until the taxonomy is resolved one way or the other.

Most of the knowledge of this species is of recent origin, coming largely from the work of Jackson in Victorian streams (Jackson 1975, 1978a,b).

4.3.1. Distribution within the State.

The most recent map showing blackfish distribution in Tasmania is given by Frankenberg (1974). This shows that G. marmoratus is found along the north coast of the state and also in the Derwent and Huon Rivers in the south. Several other distribution records were given by Johnston (1883), Seal et al. (1883) and Sloane (1978). The distribution pattern is the result of several introductions to areas where the blackfish did not previously exist. Johnston (1883) and Seal et al. (1883) report that the South Esk River was artificially stocked by pisciculturists in 1859 and Saville-Kent (1886b) was of the opinion that the blackfish "might be profitably introduced into the Derwent and other Southern rivers." Such an introduction was later made into the Derwent (Saville-Kent 1897) and Huon Rivers and they are nowadays plentiful in some tribu taries in these systems. There is reference to blackfish in the Franklin River (Gordon system) and the Henty River (Seal et al. 1883) but the records are not definite and the species has not been recorded from the Bass Strait Islands which is surprising considering that they are present in most southern Victorian rivers.

4.3.2 Habitat.

The habitat of the blackfish has not been studied in detail in Tasmania but several authors have briefly remarked on its apparent liking throughout its range for slow flowing pools preferably with fallen logs and considerable forest cover (Johnston 1883; Seal et al. 1883; Stead 1908; Ogilby 1913; Parrish 1966; Pollard 1969; Lake 1971; Scott et al. 1974).

The habitat preferences of G. marmoratus have recently received closer scrutiny in western Victoria (Jackson 1975). In this study Jackson examined statistically the blackfish catches in 62 stream sections each classified as riffle, run, cascade, flat or pool. The blackfish were restricted to the slow flowing flat and pool sections with a few specimens only in the riffle sections. Multiple regression analysis showed that there was a negative relationship between blackfish numbers and mean current velocity. Amount of cover and depth were not found to effect blackfish numbers significantly (Jackson 1975). However, these observations were all made in the daytime and could be subject to change at night as anglers report that the blackfish is more active at night. (see below).

The association of blackfish with other fish species and with stream order was investigated in several areas in Victoria (Jackson 1975). The results are difficult to interpret as the stream types were varied. Positive associations were found between trout and blackfish in some areas but the stream orders in which this occurred varied with collection sites. Hence for thorough assessment of these relationships Jackson's (1975) data should be studied more thoroughly.

Movement of G. marmoratus within an area was also studied by Jackson (1975). He tagged a total of 62 fish (adult) returning them to the site at which they were captured. He later made a total of 68 recaptures, 67.6% of which were from the same 20 m section in which they were liberated and 86.7% were recaptured within 40 m of their site of release.

4.3.3 Food and Feeding Behaviour.

The diet of the blackfish has received considerable study in Victoria (Butcher 1945, 1946; Jackson 1975, 1978b;) but not in Tasmania. Butcher (1945, 1946) examined stomach contents of blackfish collected by anglers (hence from December to April) from unspecified localities in Victoria. Aquatic invertebrates constituted 84% of the total diet (66% Trichoptera) with 16% being of terrestrial origin. Using similar methods, i.e. percentage occurrence, Jackson (1975) compared his results with those of Butcher (1945). From 94 stomachs examined he also found that aquatic invertebrates formed the major part of the diet but in this case Ephemeroptera were the dominant group (53%). As pointed out by Jackson (1975) the data of Butcher (1945) do not contain any details of the invertebrate fauna of the sites from which his samples were collected. Jackson (1975) found that Ephemeroptera were an abundant food source in his sample areas. From Jackson's data there appears to be some variation in diet with sample site but he does not elaborate on this.

Jackson (1975, 1978b) also analysed his feeding data by the rank method but comparisons of the two methods used yielded essentially the same conclusions. Jackson (1975) also briefly examined the variation in diet with size. He divided his results into two groups consisting of those below 120 mm and those above 120 mm corresponding to the 0+ and 1+ age group and 2+ and above age group. The main differences observed were the larger proportion of dipteran larvae in the smaller fish and a larger terrestrial invertebrate content of the diet of the larger fish.

Forage ratios were also investigated by Jackson (1975, 1978b) for the blackfish with generally expected results. It was found that ratios which indicated a positive preference were obtained for most of the species forming the major part of the blackfish diet. These species were usually the major components of the benthos with some exceptions such as the dipteran larvae. However the dipterans may not have been accessable rather than unwanted. Hence the forage ratio may be useful in some cases but considerable attention should also be given to the time, place and method of feeding of the particular fish in question as certain benthic species may becomemore easily available (such as in drift) at certain times. Such a change would not be reflected by standard benthic samplig procedures usually used in fish food studies. Jackson (1978) took benthic samples from cascade, riffle, run and flat sections of the stream he studied yet the blackfish is common only in the flat sections as well as the pools which were not sampled for benthos.

### 4.3.4 Life History.

Although the blackfish is one of the larger and more common of our native fishes its life history was largely unknown until the recent work of Jackson (1975, 1978a). A few early authors remarked on the breeding time and low fecundity of the species but little other study was made.

#### 4.3.4.1. Age and Growth

It was found that the first two age classes of the blackfish were easily recognisable in the Victorian population

studied by Jackson (1975). He was able to study the growth of the 0+ year class through two years and the 1+ class through one year of growth. On average, fish grew to a length of 47 and 58 mm after one year in 1972 and 1973 respectively and to 122 mm after the second year. The 0+ age group were of considerably different size on first appearance in the samples in the two years studied by Jackson (1975). There was already a 15 mm size difference (33.2 and 48.3 mm for Autumn 1972 and 1973) in the young fish which decreased slightly by the end of the first year. The reasons for the difference were not clear but could have been related to density-dependant factors as the 1972 0+ year class appeared more abundant than the 0+ year class in 1973 (Jackson 1975).

Graphs of growth in length and weight for the blackfish showed that little or no growth occurred during the late autumn and winter period whilst most rapid growth occurred during spring and early summer (Jackson 1975).

Observations on the growth of older blackfish from tagging data were made (Jackson 1975). There was still some evidence of higher growth rates in summer with a mean daily instantaneous growth rate of 0.166 mm compared with a winter value of 0.035 mm. He gives an average daily instantaneous growth rate for tagged fish between 200 and 300 mm as 0.079 mm. However on examining Jackson's (1975) data it appears that he has ignored fish in this group which showed no growth during the mark-recapture period. If these are included the figure becomes 0.056 mm. Jackson compares the growth rate to that of brown trout from the same area (0.066 mm).

Jackson (1975) captured fish to a maximum length of486 mm however the blackfish may grow to a much larger size, particularly in Tasmania. Johnston (1883) reports that they had been known to reach 4-5 kg. in the Ringarooma River. This weight is also recorded by Seal et al. (1883) who report that blackfish may exceed 75 cm in length. Stead (1906) records that it may exceed 70 cm and Ogilby (1913) quotes a letter from northern Tasmania which stated that 5.5 kg specimens had been caught and 3.2 kg specimens were not uncommon.

Specimens of such large size have not been recorded of late but recent above average Tasmanian records are a 2.05 kg, 558 mm specimen from the Black River as well as a 3.37 kg fish from the Leven River (Lynch 1974) and a 2.26 kg, 533 mm specimen caught near Mawbanna (Lynch 1976). The maximum age attained by G. marmoratus has not been recorded and it does not appear that scales or otoliths of this species have been examined.

4.3.4.2 Maturation and fecundity.

It was earlier thought that the blackfish was hermaphroditic (Johnston 1883; Seal et al. 1883) as male fish had not been observed among large numbers of female specimens. Such information was quoted by Ogilby (1913) but he did not make any comment and the idea died a natural death. Male and female blackfish do exist and their maturation was studied by Jackson (1975). He found that blackfish mature by November after they have reached a size of 150 mm with all fish maturing by the time they reach 300 mm. These lengths correspond to the third and fourth years of life (Jackson 1975).

Fecundity in this species was found to be low by Jackson

(1975) with egg number ranging from 42 to 309 in the fish he studied. There was a clear linear relationship between egg number and body length as shown below:

Egg number = -113.85 + 1.27 body length.

The fact that the fecundity of this species was quite low was also reported earlier in the literature (Ogilby 1913; Whitley 1960; Lake 1971). It was also reported that the eggs were large in size. Lake (1971) gives the size at about 4 mm diameter and a mean diameter of 3.95 mm was found by Jackson (1978a).

4.3.4.3 Breeding biology.

It was found that spawning took place in November (Jackson 1975). Blackfish spawning in the October-December period has been recorded earlier (Seal et al. 1883; Stead 1908; Ogilby 1913; Whitley 1962; Pollard 1969). Further more specific data on spawning time is given by Jackson (1978a).

Jackson (1975) attempted to observe spawning in an aquarium but although the female deposited her eggs in a group of stones the male did not fertilise them. A similar spawning site was observed in an aquarium by Proebsting et al. (1974) but the eggs did not develop in this case either. At this stage the normal spawning behaviour of the blackfish has not been observed.

The spawning site has been speculated upon by several authors. Ogilby (1913) suggested that eggs were deposited on stems of grasses in the bed of streams, Whitley (1962) stated that the eggs were adhesive on submerged objects and Lake (1971) suggested that ova were probably laid in a nest in the gravel. It has been observed by several authors that the eggs are demersal and adhesive (Ogilby 1913; Whitley 1960, 1962; Pollard

1969; Lake 1971; Jackson 1975). Jackson (1978a) appears to be the first to observe actual spawning sites of wild fish. He discovered five sites in the McKenzie River, Victoria, all of which were inside hollow logs. As pointed out by Jackson this may not be the only spawning site used but despite thorough searching elsewhere in rivers (Jackson 1975) none other had been found. It has also been observed that blackfish will spawn in ponds (Pollard 1969; Lake 1971).

Details of blackfish spawning sites are given by Jackson (1978a). Log size, water depth and current velocity are given but as stated by Jackson some of these could reflect sampling bias. The eggs were laid in a single layer in a tightly packed irregular mass on the bottom surface of the hollow log. They had flattened surfaces along contact lines, particularly with the log surface. As all the eggs were at a similar stage of development and ranged in number from 21 to 246 between sites it appears that each site was used by one fish only and that spawning took place over a short time (Jackson 1978a).

An adult blackfish was present in each of three logs when they were removed from the water by Jackson (1975). One of the fish was captured and found to be a male which had not been feeding on eggs. Proebsting et al. (1974) noted that eggs were guarded in an aquarium by an adult fish which left them only occassionally to feed. From these findings, Jackson (1978a) suggested that the eggs were given some parental protection.

4.3.4.4 Embryology and early development.

Jackson (1978a) observed eggs which were apparently recently deposited. Membranes were soft and the eggs were pale yellow and only slightly adhesive. After four hours the membranes were hard and eggs were orange and strongly adhesive. Hatching of these eggs was observed after 16 days at which stage Jackson

(1978a) described the young blackfish as an eleutheroembryo (after Balon 1975). They were 6.4 mm TL at this stage. Other eleutheroembryos at the same stage ranged in size from 6.2 to 8.0 mm (mean 7.35 mm). They lacked body pigmentation but the eyes were prominent and the median fin fold well developed. The yolk sac was large and still attached inside the chorion with only the actual embryo section becoming free at that stage. The chorion remained attached to the log substrate for a further 19 days after which time the eleutheroembryos wriggled free and dropped to the bottom of an aquarium to which the log section had been removed. A specimen at this stage measured 13.6 mm and was able to swim for short periods but preferred the cover of leaf litter at the bottom of the aquaria. The yolk sac was not fully absorbed for a further 7 days and the fish then began to forage in the leaf litter.

The eleutheroembryonic stage, therefore, lasts at least 26 days after which the fish is fully developed. Hence there is no larval period in the development of the blackfish. Temperatures during these early stages observed by Jackson (1978a) ranged from 7 to 24°C with a mean minimum of 11°C and mean maximum of 17°C.

4.3.5 Diseases, Parasites and Natural Predation.

No diseases have been recorded as effecting the blackfish. The only parasite recorded from the species is the nematode, Eustrongylides gadopsis which was present in fish from New South Wales (Johnston & Mawson 1940).

There is no evidence of natural predation upon the blackfish in the literature. As one of the largest native species present in Tasmanian streams it is unlikely that

the blackfish would be subject to any serious natural predation from other fish species. There is no evidence to suggest any intra-specific competition either.

4.3.6 Competition.

Lake (1971) listed the blackfish as a seriously threatened species and indicated that it was once more abundant than it now is in some areas. Other authors have also remarked on its apparent reduction in numbers (Butcher 1967; Pollard 1969; Scott et al. 1974) but they do not refer specifically to the Tasmanian area. Lynch (1974) reports that anglers had noted a decline in Tasmanian blackfish stocks.

Some authors have suggested that the declines have most likely been due largely to habitat alteration particularly the de-snagging of streams (Butcher 1967; Lake 1969; Scott et al. 1974). Some Australian authors (Butcher 1967; Weatherly & Lake 1967) have favoured blaming man's alteration of the environment and not the introduction of trout for the decline of native fish species in the absence of adequate evidence to support either case. From the blackfish breeding study results of Jackson (1978a), it is now obvious that river improvement practises such as those reported on by Turnbull (1977) could have drastic effects on the breeding of this species, as would siltation caused by poor land usage. Such river clearing practises would also result in increased current velocities a factor to which blackfish were found to be negatively correlated (Jackson 1975).

Jackson (1975) found great similarity between the diet of both blackfish and brown trout in his Victorian study area

and concluded that competition existed. However, as pointed out by Jackson, the definition of competition he used was merely dependant on both species utilising a potentially limiting food source, which was the case. He did not attempt to examine feeding behaviour, site or time.

Blackfish have definite habitat preferences (Jackson 1975) but these areas are now also occupied by trout. Hence in the absence of accurate data on blackfish numbers in these areas before the introduction of trout it is difficult to prove that the blackfish have actually been displaced by trout. Jackson (1975) did indicate that trout had competitatively displaced a Galaxias sp. from some stream sections he studied. He concluded that "Differences in spawning requirements, habitat preferences, and possibly feeding behaviour, were considered to be factors allowing the co-existence of brown trout and blackfish in highland streams."

It appears from the above data that the blackfish has more to fear from the agricultural and stream improvement practices of man than from competition with other fish species.

### 4.3.7 Use as Food.

The blackfish has long been recognised as a very fine eating fish (McCoy 1879; Johnston 1883; Seal et al. 1883; Ogilby 1893, 1913; Anderson 1900; Stead 1906, 1908) although some do not agree (Scott 1962; Scott et al. 1974). There is more widespread disagreement on the angling qualities of the blackfish however, with some of the above stating that it "shows fight" while others rate its angling qualities as practically nil. It is recorded that some very large Tasmanian catches were made by rod and line such as the 1 cwt. by two

men in a night (Seal et al. 1883) and 24 dozen by three rods in one night (in Ogilby 1913).

Whatever the fishing qualities it is still a popular fish with anglers. It is reported that the blackfish is best caught at dusk with gear that has apparently seen little change since the early days of angling in this state (Seal et al. 1883; Anderson 1900; Pollard 1969).

# CHAPTER 5 THE GALAXIIDS

This group markedly dominates the Tasmanian native freshwater fish fauna and some of the members of the group are the most numerous and widespread native fish in the state. Taxonomically the Tasmanian galaxiids received most attention from workers such as Scott, Whitley and Stokell. But until the work of Andrews the taxonomy was in a state of chaos. Interest has now been revived and with numerous papers by McDowall and others by Frankenberg and Fulton the group is receiving some long warranted taxonomic and ecological attention. A paper by McDowall and Frankenberg at present in preparation should tidy up any loose ends in the taxonomy of the entire galaxiid group throughout its known range.

Three genera of galaxiids are present in Tasmania; Galaxias, Galaxiella and Paragalaxias with the majority of the species belonging to the first genus. With the exception of the jollytail, Galaxias maculatus, there is a lack of published data of an extensive biological nature on any of the Tasmanian species. G. maculatus has received some attention elsewhere, particularly in New Zealand, probably because of its commercial importance as the major fish of that countries whitebait industry.

Lake (1978) lists the food of most species of galaxiids as consisting of small invertebrates mainly arthropods and aquatic insects, but this is probably a generalisation by this author rather than the findings of any study. Boyle (1975) has briefly outlined the anatomy of the olfactory system and brain of most of Tasmanias species. Hence unless other data exists on those subjects the two references are not included under the individual headings to avoid repetition.

The species are treated in alphabetical order and details are arranged into separate sections for each species only where sufficient material exists.

## 5.1 Galaxias auratus; (golden galaxias).

This endemic species is well known to the trout fishermen of Lake Crescent who use it as bait for the large brown trout of that water. It was first described by Johnston (1883) and is also adequately described by Andrews (1976). Further details of morphometric and meristic variation of the species are given by Fulton (1978a).

### 5.1.1 Distribution within the State.

There was considerable confusion about the type locality of this species in the early literature probably arising from the original description by Johnston (1883) which states that the "species is confined to the neighbourhood of Great Lake." Many later authors then gave the locality merely as Great Lake (McCulloch 1929; Scott 1936a; Munro 1957). The error was later corrected by Andrews (1976).

Frankenberg (1974) gives the distribution of G. auratus as "Lakes Crescent and Sorell and their distributary, the Clyde River in the Derwent system." The species is present in some tributaries of these lakes but it does not appear to penetrate far into them. It also appears not to move far down the Clyde River from its origin in Lake Crescent.

### 5.1.2 Life History.

The life history of this species is virtually unknown.

Frankenberg (1974) stated that it is essentially lacustrine with a life cycle passed entirely in freshwater.

Andrews (1976) reports that it is one of the largest of Tasmanias galaxiids reaching a standard length of 217 mm but specimens he studied were mainly 100-120 mm in length.

The maturation stages of the fish studied by Andrews (1976) and the presence of 15-19 mm post-larval G. auratus observed in Lake Crescent during December 1970 indicate a late winter or early spring spawning season.

As mentioned above G. aurutus is widely used as a trout bait in Lake Crescent, it also forms a major part of the natural diet of brown trout in that lake. Lynch (1968a) found that large numbers of G. aurutus (he wrongly named them G. truttaceus truttaceus) were present in the stomachs of brown trout from Lake Crescent but that the pressure of trout predation appears to be having little effect on the G. aurutus population.

## 5.2 Galaxias brevipinnis; (climbing galaxias).

The first specimens from Tasmania attributable to this species are probably those described by Johnston (1883) from the Mersey River as G. weedoni and from the Pieman River as G. atkinsoni. Specimens collected from lacustrine habitats were later described as G. affinis (Regan 1905) and G. parkeri (Scott 1936a). Frankenberg (1967) found specimens of G. brevipinnis on the Bass Strait Islands which he identified as G. coxii. The problem of the multiplicity of names was eventually sorted out partly by McDowall (1970a) and completed by Andrews (1976). Both these authors give adequate descriptions of this variable species, the latter using predominantly Tasmanian specimens.

### 5.2.1 Distribution within the State.

This species has the widest distribution throughout Tasmania

of any of the state's galaxiids. Distribution maps given by Frankenberg (1974) (for G. coxii) and Andrews (1976) show that it is found on both Flinders and King Islands in Bass Strait, in coastal streams around all sides of the state and in many lakes and tarns further inland. Both of these maps are far from complete and observation of the early part of the "whitebait" run in coastal streams would undoubtedly increase the distribution records for this species.

McDowall (1970c) remarks that physical barriers in streams have less effect in preventing upstream migration in G. brevipinnis than other New Zealand species because of the exceptional climbing ability of this species. Such climbing ability no doubt explains its presence in many alpine lakes in Tasmania.

5.2.2 Habitat.

Before detailed taxonomic examination of the species by McDowall (1970c) G. brevipinnis was known in New Zealand under its various synonyms as the cold lakes galaxias, (G. lynx), thermal lakes galaxias, (G. koaro) and lowland galaxias (G. brevipinnis) (Stokell 1955). Hence it is evident that this species is able to survive in many varied habitats. Both diadromous and lacustrine populations are known in New Zealand (McDowall 1970c) and Tasmania (Frankenberg 1974; Andrews 1976).

McDowall (1970c) found it was unusual for G. brevipinnis to occur around the shores of lakes in New Zealand although they did occur in such places in some lakes. He found that the adults were more often found in tributary and distributary streams. I have found many more G. brevipinnis present amongst rocks around the shores of Tasmanias Central Plateau lakes than I have in their tributary streams. Andrews (1976) considered that Tasmanian

lacustrine populations of this species do not appear to have any habitat preference but were found fairly evenly distributed even in deep water. However Andrew's method of capture, which was almost entirely by use of baited traps, would not have given him a complete indication of habitat preference.

The adult fish are essentially benthic in lakes and are seldom seen in large numbers, however the juveniles shoal, often in extremely large numbers, during spring and summer, (Scott 1936a; Stokell 1955; Woods 1963; McDowall 1970c, 1978a; Andrews 1976).

Stokell (1955) although referring to the species as a lowland dweller found that "it inhabits rapid, rocky streams in proximity to bush...." This is essentially similar to the habitat described by McDowall (1970c) as "small, cold, rapidly flowing, stable rocky streams which are often heavily overgrown with bush." McDowall (1970c) also found that G. brevipinnis is very secretive but may form dense populations in streams unmodified by forestry and agricultural development.

Nothing is known of the riverine juveniles until they migrate into the lower reaches of streams in spring. McDowall et al. (1975b) found some galaxiid specimens at sea which may have been G. brevipinnis. Scott (1936a) found that juvenile G. brevipinnis from tributary streams of Great Lake, Tasmania migrated into the lake in large numbers near sunset and returned the following morning. This pattern of migration has not been observed elsewhere. McDowall (1978a) considered that the juveniles of the lacustrine form migrate into the tributary streams usually in spring to take up their adult habitat. I have found that this migration is usually seen in Tasmania in summer to early autumn rather than spring.

5.2.3 Food and Feeding Behaviour.

Although the species is quite widespread and well known

its food has received little study. Eldon (1969) observed that G. brevipinnis was essentially a bottom feeder. Stokell (1955) found that, during its lake existence, its food consists mainly of copepods whereas riverine G. brevipinnis usually eat midge and caddis larvae. The number of stomachs examined has not been given for either locality hence the reliability of the conclusions is questionable. Phillipps (1930) considered that G. brevipinnis may feed on mosquito larvae hence be of some use in the control of these insects.

5.2.4 Life History.

The study of the life history of G. brevipinnis is complicated by the fact that it may have a marine juvenile phase or it may pass its entire life in landlocked conditions. It appears that the two forms normally breed at different seasons in Tasmania at least. However there are certain parallels in the life history of both forms.

5.2.4.1 Age and growth.

McDowall (1970c) records that G. brevipinnis is one of the larger of the galaxiids. He later states (McDowall 1978a) that this species reaches a known maximum size of 270 mm. Andrews (1976) records that the largest Australian specimen was 200 mm (SL). A Tasmanian specimen in the collections of the Inland Fisheries Commission measures 208 mm (TL) and two heads of the same specimens held in these collections are certainly from larger individuals.

The young of riverine populations first appear in spring whitebait catches both in New Zealand (McDowall 1964c, 1965; Woods 1966, 1968a) and Tasmania (Lynch 1965a; Anon 1968a). Woods (1968a) gave the standard length of a sample of G. brevipinnis whitebait from New Zealand as 42.3 mm $\pm$ 1.31 S.D. McDowall (1978a) states that the whitebait of this species are 45-55 mm long (probably TL).

As recorded for G. maculatus, Woods (1968a) shows that G. brevipinnis undergoes shrinkage in length after they move into freshwater. Woods (1968a) observed that the fish feed during shrinkage so he assumed that it was an active rather than wasting phase.

Associated with the movement into freshwater is the onset of a discernable pattern of pigmentation. The fish begin to assume a colour pattern during shrinkage and the development of this pattern is detailed further by Woods (1968a) and McDowall (1970c)

Few details are available on the growth rate of G. brevipinnis Eldon (1969) made some observations on captive fish and observed that fish may grow to in excess of 90 mm in their first year. He gives lengths of 87 to 103 mm and 78 to 102 mm for one year old fish measured in November of two successive years from a Wellington stream. From other limited data given by Eldon (1969) it seems that growth rates are much slower after the first year and that the fish may live at least four years in freshwater. McDowall (1978a) stated that G. brevipinnis may live for 6-8 years or more.

5.2.4.2 Breeding biology.

Spawning migrations have not been observed for G. brevipinnis and it is probable that spawning occurs in streams near the adult habitat as ripe adults have been observed in such areas (McDowall 1970c). In riverine populations spawning occurs in autumn or early winter (Frankenberg 1969; McDowall 1970c, 1978a) and on hatching the larvae are washed to sea or lake. McDowall (1970c, 1978a) considered that the lacustrine populations were of similar habit. I think that McDowall has oversimplified the case in that it appears at least that lacustrine populations probably breed in spring in Tasmania. Some evidence of this is given by Andrews (1976) for lakes draining into Lake

St. Clair and I have similar data from Great Lake. McDowall (1978a) records that lacustrine 'whitebait stage' G. brevipinnis are commonly found in New Zealand lakes in spring but they are normally observed in Tasmanian lakes in late summer.

McDowall (1970c) records that "The eggs of G. brevipinnis are of moderate size and numerous, 1.3-1.6 mm diameter in a female 188 mm long and carrying about 7,500 eggs." The exact spawning site or spawning behaviour have not been described.

5.2.4.3 Migrations

After hatching the larval G. brevipinnis undergo a passive migration to sea or lake. McDowall (1978a) states that the larvae are planktonic in the surface water of lakes and probably also in the sea as galaxiid larvae have been collected in plankton tows at sea (McDowall et al. 1975b). The marine larvae then migrate into freshwater in spring forming large shoals. These shoals are also apparent in New Zealand and Tasmanian lakes and McDowall (1978a) reports that the Moaris exploited the freshwater whitebait runs. McDowall (1978a) found that the lacustrine G. brevipinnis whitebait migrate up tributary streams in the same manner as those of marine origin. Migrations of young G. brevipinnis have also been observed in Great Lake Tasmania (Scott 1936a).

The remarkable climbing ability of G. brevipinnis, mainly attributable to the large pectoral and pelvic fins of the whitebait stage, is of considerable importance during the migration phase. As this species usually inhabits the swifter flowing sections of streams this attribute assists them in

reaching such areas. Quite sizeable barriers are often negotiated in the process and hence G. brevipinnis can move to waters often out of reach of other species of fish.

5.2.5 Behaviour.

Scott (1936a) remarked on the resting appearance of G. brevipinnis. He found that the body was held horizontally supported by the tips of the outstretched pectoral and pelvic fins.

Woods (1963) and Eldon (1969) noted that G. brevipinnis was an active and inquisitive fish in captivity. Eldon (1969) further noted however that G. brevipinnis became much more secretive when another species of fish was placed in a tank with it.

5.2.6 Parasites and Natural Predation.

Scott (1936a) observed that some specimens of G. brevipinnis collected from Great Lake, Tasmania were heavily infected with an opisthorciid trematode. He also observed that the species was liable to Saprolegnia attack.

McFarlane (1939) described the occurrence of the trematode Coitocaecum anaspidis from the intestine of G. brevipinnis in New Zealand. The trematode species, Telogaster opisthorchis, Stegodexamene anguillae and Rhyllodistomum anguillae have also been recorded from this species in New Zealand (McFarlane 1945, 1951, 1952; Hewitt and Hine 1972). Fryer (1969) described a new species of branchiuran, Dolops tasmanianus, which was found to be parasitic upon G. brevipinnis in Lake Surprise, Tasmania.

No details of the effects, if any, of the above parasites on G. brevipinnis have been given by any of the above authors.

There are no records of natural predation upon G. brevipinnis but, as stated for G. maculatus later in this chapter, the fish and birds listed by Blackburn (1950) as predators of Lovettia sealii probably prey upon juvenile G. brevipinnis during their upstream migrations. Brown trout, although not strictly natural predators, have been shown to feed on many species of Galaxias and G. brevipinnis would be no exception to this (Phillips 1924b; Sapworth 1945). However it appears that predation by trout may have or already have had serious effects on adult stocks of G. brevipinnis. This is dealt with further in the following section.

5.2.7 Competition.

There is no published information on intra-specific competition in G. brevipinnis nor is there any data on competition if any, between this species and any other native freshwater fish. The area where competition appears likely is between G. brevipinnis and the introduced salmonids particularly the brown trout, Salmo trutta, and the rainbow trout S. gairdneri. Several authors have indicated that trout introduction and galaxiid decline have been concurrent in many areas (Fish 1966; Frankenberg 1966; McDowall 1968a; Tilzey 1976). It is probable that some of the evidence could be dismissed as circumstantial but the work of Tilzey at least seems conclusive. Although the study was mainly concentrated on Galaxias olidus this species occupies similar habitats to G. brevipinnis. Tilzey (1976) concluded that the "Available evidence suggests that G. olidus and G. coxii populations in certain lotic habitats diminished or dissappeared following the introduction of Salmonidae."

(G. coxii = G. brevipinnis). Frankenberg (1966) had earlier suggested that salmonid introduction had caused similar declines in some lentic waters. Further evidence suggesting that the salmonids and galaxiids are not compatible particularly in rivers is given by Jackson (1975).

Trout are now present in most of Tasmanias inland waters and although G. brevipinnis is present in many of these to my knowledge it is never common where trout also occur in a riverine habitat. G. brevipinnis is still very common in some high level lakes and tarns where trout have not been introduced.

5.2.8 Use as Food.

Best (1929) reports on the methods employed for catching whitebait by the New Zealand Maori. It is most likely that G. brevipinnis formed part of this catch. Phillipps (1921) and McDowall (1978a) report that the Maoris fished for juvenile G. brevipinnis in some New Zealand lakes. More recently this species has formed part of the commercial whitebait catches of New Zealand and Tasmania (Lynch 1965a; McDowall 1965, 1972c; Woods 1966; Anon. 1968a).

McDowall (1965) recorded that G. brevipinnis was the second most important component of the New Zealand whitebait catch for the 1964 season at least. The species composition of the Tasmanian whitebait catch is contained in the Annual Reports of the Tasmanian Inland Fisheries Commission (see Lynch 1964-1978). G. brevipinnis made up a small portion of the September and/or October catches in 1964 and 1965 (Lynch 1965, 1966). This species probably ranks fourth in importance in Tasmania's fishery and although it is not recorded in the whitebait catches subsequent to 1965 it was almost certainly present from some

areas in the early part of the season.

5.3 Galaxias cleaveri; (Tasmanian mudfish).

The record of Hall (1901) of a specimen of Galaxias collected from decayed peat and sand at Strahan is probably the first observation of G. cleaveri from Tasmania. The species was first described by E.O.G. Scott (1934) from a specimen collected by Mr. F. Cleaver from near Ulverstone. Further details of this and other synonyms of the species as described by Scott (1936, 1942b) are given by Andrews (1976). Although species with similar habits are found in New Zealand (Neochanna spp.) G. cleaveri is restricted to Tasmania.

5.3.1 Distribution within the State.

Frankenberg (1974) shows that G. cleaveri is found around most of the coast of Tasmania with the exception of the east coast. He also remarks that it has not been found on the Bass Strait Islands. Andrews (1976) suggests that G. cleaveri is probably "more or less continuosly distributed around the southern, western and northern coastlines in all suitable swampy areas.

Collections of G. cleaveri have often been by accident owing to its burrowing habit, hence many populations have probably escaped detection.

5.3.2 Habitat.

There is little biological data available on this species but from what is known it is apparent that it has evolved to live in the low lying coastal swamp areas around Tasmanias coastline

Hall (1901) records that the specimen sent to him from Strahan "was found in decayed peat and sand eight inches below the surface". Scott (1934) records that the specimen from which he described G. cleaveri was found inside the root of eucalyptus stump which had been blasted from the ground. Surface water was absent from both the above sites at the time of collection. I have collected specimens of G. cleaveri from damp earth under logs and rocks near the banks of the Gordon and Esperance Rivers. Andrews (1976) states that specimens were collected from mud in stagnant pools at Port Davey.

From the above observations it is clear that part of the adult life cycle is passed away fromfree water. There are no details on the habitat of juvenile G. cleaveri.

This species is essentially similar to the three New Zealand mudfish in habitat and more details of one of these species are given by Eldon (1968).

5.3.3 Food and Feeding Behaviour.

Andrews (1976) considered that G. cleaveri appears to be a detrital feeder as the stomach contents he examined contained "substrate material mixed with chitinous insect remains." He also considered that the large pyloric caeca found in this species would enable it to better handle large volumes of material of low nutritive value.

5.3.4 Life History.

There are no data on age of G. cleaveri and growth data are limited to Andrews (1976) observations of the size of specimens he studied. The largest specimen he observed was 125 mm with the remainder from 70-120 mm in length.

Andrews (1976) also found that a specimen collected "during May 1969 contained almost fully developed eggs of 1.3-1.5 mm diameter." He considered that a late winter or early spring spawning time was likely. I observed large numbers of juvenile G. cleaveri about 3-4 cm in length migrating into small runnels and puddles of free water in the Southport area during the first week of December, 1978. From the size of these fish I think an early to mid winter spawning time is likely. McDowall (1978a) suggests that the New Zealand mudfish species may spawn over an extended period but often this happens soon after their aestivation site is covered by water.

Several authors have noted that G. cleaveri can survive out of water for some time (Hall 1901; Scott 1934, 1936a, 1942b; Andrews 1969, 1976; Frankenberg 1974) and it is known to aestivate when free water dries out from its habitat. It has also been observed to quickly become active again once taken from aestivation and placed in water. Unfortunately no other details are available on its life history.

5.3.5 Competiton.

There has not been any published data on competition of any nature dealing with G. cleaveri. Andrews (1973) did find other galaxiid species (G. maculatus and G. truttaceus) present in the same area as G. cleaveri but no evidence of competition was suggested. Frankenberg (1974) stated that G. cleaveri "is popular as live bait" with trout fishermen but I have not heard of it being widely preyed upon for this purpose.

The mudfish although widely distributed, probably has more to fear from man's alteration of its habitat than any other galaxiid species in Tasmania. The drainage and reclamation of

low lying swampland has already lessened the area suitable for this species and unless some effort is made to conserve such areas this species along with other wetland animals are in danger of disappearing from many parts of the state.

5.4 Galaxias fontanus; (Swan River galaxias).

This riverine species was described in 1978 from specimens first collected two years earlier (Fulton 1978b). The species description paper provides the only published data on this fish.

The detailed habitat is not described but the species appears to be confined to one river system only and probably passes its entire life in that system. A marine phase in the life history is not indicated as adult and small juvenile fish were found at the collection site (Fulton 1978b). The maximum size for the species observed by Fulton was 96 mm TL.

From the limited information given on gonad development and the fact that 20 mm long juvenile fish were reported in January-February it appears that spawning probably occurs about October or November , however much more detailed study is required on this species. The limited distribution of the species makes it extremely vulnerable to habitat alteration wether by introduction of exotic species or physical alteration of the environment.

5.5 Galaxias johnstoni; (Clarence galaxias).

Since the original description of the species by Scott (1936a) there has been little discussion of it. This is probably largely due to the fact that very few specimens have been collected. Andrews (1976) reports that only nine specimens were known, three of which (those referred to by Frankenberg 1974) could not be located. His only option therefore was to leave the

taxonomic position of the species intact in the absence of sufficient data to decide otherwise. I have since collected a series of approximately fifty specimens which will allow more thorough evaluation of some doubts raised by Frankenberg (1969).

The species is confined to a small section of the upper Derwent drainage system in Tasmania. Scott (1936a) collected his type specimens from Brown's Marsh Rivulet, a small tributary of the Nive River. The species has also been collected from Clarence Lagoon (Andrews 1976) but has not been recorded from the Clarence River as is assumed by Andrews (1973, 1976) nor the Nive River as stated by Frankenberg (1974).

No details of the life history of this species have been published. However from my collections it appears that the entire life is passed in freshwater. Juvenile fish not unlike G. brevipinnis in appearance and size were collected in Clarence Lagoon during autumn hence a late winter spawning time is suggested. The size range of the specimens I collected indicates that the original description of G. johnstoni (Scott 1936a) was probably based on fish less than one year old and that the three specimens referred to by Frankenberg (1968), the lengths of which were given by Andrews (1976) as 40-60 mm, were of similar age. About half of the fish I collected in autumn were of this size and were abviously less than one year old hence it is probable that the only adult specimen examined until this collection was the 81.3 mm specimen mentioned by Andrews (1976). For this reason the descriptions of G. johnstoni (Scott 1936a; Andrews 1976) are inadequate and require further study. (The largest specimen I collected was in excess of 120mm long).

Scott (1936a) found that G. johnstoni is often parasitized by what he called an opisthorciid trematode. The metacercaria are evident in the photograph published by Andrews (1976).

Lake (1978) gave brief details of diet of G. johnstoni. He stated that the food consists of "small invertebrates mainly arthropods and aquatic larvae" however in the absence of collected specimens I don't know where this data came from.

Galaxias johnstoni appears to be one of the most "delicately placed" populations of Tasmanian native fish. It seems that it is no longer present in the river systems near Clarence Lagoon (it is notknown ifit ever was abundant in this habitat however). At present there is no effort being made to establish its distribution and hence when some effort finally is made (if ever) it may well be too late.

## 5.6 Galaxias maculatus (jollytail).

This species is the most widely distributed of the galaxiid species. It is a commercially important species forming the basis of the whitebait catch in New Zealand (McDowall 1965) where it is known by the Maori name "inanga". Probably because of this commercial importance, but also no doubt due to its ease of capture, it has been the subject of several major papers in New Zealand (Burnet 1965; Benzie 1968a, b; McDowall 1968b) and Victoria (Pollard 1971a,b; 1972a,b).

The species was first described by Jenyns (1842) as Mesites maculatus from material collected from Patogonia. In the same paper Jenyns also described another species M. attenuatus from New Zealand. These species were later recognised as members of Cuvier's (1817) genus Galaxias (Cuvier & Valenciennes 1846).

The Australian and New Zealand form continued to be known as G. attenuatus until the synonomy of the two species was suggested by Stokell (1949) and later confirmed by McDowall. (1967b). The choice of 'maculatus' as the specific name was not favoured by the latter author as it was not as widely used as was 'attenuatus' however the revision has been accepted by recent Australian authors (Pollard 1971b; Frankenberg 1974; Andrews 1976).

Recent descriptions of the species are given by McDowall (1970c) and Andrews (1976) and these two authors also give morphometric and meristic data, as does Pollard (1971b) for a landlocked Australian population.

5.6.1 Distribution within the State.

Frankenberg (1974) states that the species "probably occurs in the lower portions of most Tasmanian streams" and he records it from King Island and Flinders Island in Bass Strait. Andrews (1976) found it to be common in all the coastal streams he studied but considered that it appeared unable to penetrate far inland as he did not find specimens further than 14 km from the sea. I have collected specimens at least 30 km up from the mouth of the Gordon River but generally the species is more common in the lower reaches of our rivers and streams probably all round the state.

5.6.2 Habitat.

The adult habitat of G. maculatus has received little study with most authors merely saying that the species occurs in lowland streams. McDowall & Whitaker (1975) state that they

grow to maturity "in freshwater in open, lowland streams and rivers, usually beyond tidal influence" whilst Woods (1963) noted that it was a shy species which would readily hide under banks. McDowall (1978a) stated that it was found in "lowland coastal rivers, streams, lakes and swamps, in almost any water it can reach in its migration up from the sea." McDowall considered that the species is limited to this area by its inability to climb falls or surpass long swift rapids. Some idea of the habitat of G. maculatus can be gained from the description of sample areas and food and feeding details given by McDowall (1968b) but in general this topic has received little coverage.

The habitat of the juvenile prior to its migration into freshwater is also virtually unknown as this stage is passed in the sea. McDowall et al. (1975b) give details of galaxiid larvae collected from the sea near New Zealand, some of which were referred to G. maculatus but further details of this phase are unknown.

5.6.3 Food and Feeding Behaviour.

The first study in any detail of feeding of G. maculatus in New Zealand was that of Allen (1951) this was followed in that country by the extensive study by McDowall (1968b). Prior to these some details were given by Phillips (1924a, 1926) Hefford (1932), Percival (1932) and Stokell (1955). The diet of G. maculatus in Victoria was studied by Butcher (1945) and in a landlocked Australian population by Pollard (1973a). Some brief details of the diet of the species in Tasmania are given by Bennison (1975), Sloane (1976) and Lake and Bennison (1977).

In the study by McDowall (1968b), 1,916 stomachs were examined mostly from one locality. G. maculatus was found to be a "generalized carnivore" with 98% of its food being of aquatic origin. The major items calculated by numbers present and expressed as percentage of total food items were copepods (39%) chironomids (22%) and prosobranchiate molluscs (21%). trichopteran larvae (total about 6%) coleopteran larvae (2%) and unidentified fish eggs (3%) were also present. Some fish were also present, these being specimens of unidentified galaxiids and eleotrids. McDowall (1968) records that usually most of the food items were small but occassionally large single organisms were taken and these were often of terrestrial origin.

Allen (1951) examined 14 G. maculatus stomachs and found that the average number of animals found in each was 22.7. The diet of these fish was predominantly dipteran and trichopteran larvae.

Butcher (1945) also found that the major part of the diet of G. maculatus was of aquatic origin. He concluded that whereas the food items taken by this species were essentially similar in type to those taken by the other species he studied (brown and rainbow trout, Maquarie and English perch and blackfish) they were all small forms within each group. Butcher does not indicate how many jollytail stomachs he examined but he found that 49% of the total food items were chironomids with the next major item being molluscs.

In his detailed study of feeding in G. maculatus Pollard (1973a) concluded that the overall diet consisted largely of amphipods, chironomid larvae and copepods with cladocerans, ostracods, trichopteran and zygopteran larvae being of lesser importance.

Sloane (1976) after examining a small number of stomachs found that amphipods, dipteran larvae and cladocerans were important food items of G. maculatus in the Jordan River Tasmania. Lake and Bennison (1977) found that cladocerans were of major importance followed by aquatic dipteran larvae and amphipods in the 8 stomachs they examined from the Jordan River.

The numbers of specimens examined from Tasmania is not large enough to draw conclusive comparisons with any of the other works. However Pollard (1973a) considered that there was a basic difference in diet between stream dwelling forms as given by Butcher (1945) Allen (1951) and McDowall (1968b) compared to his landlocked form. He showed that the stream dwelling forms ate mainly insects, a significant number of molluscs and some crustaceans whereas the lake form diet consisted mainly of crustaceans, a significant number of insects but few molluscs.

It could be suggested that these findings may merely reflect the abundance of the particular food items at each site however Pollard (1973a) found that G. maculatus was actually selectively feeding on some food items. McDowall (1968b) did find that the major food items in the diet changed with locality but he did not give any details of the abundance of the items in the field.

The variation in diet with growth was examined by both McDowall (1968b) and Pollard (1973a). There are no major changes to the diet with perhaps a trend for an increase in the consumption of the larger food items, such as gastropods, and a decrease in smaller ones, such as copepods, with growth. Pollard (1973a) also examined the diet of male and female fish

and found differences in the proportions of amphipods (female higher) and copepods (males higher) eaten. He considered this to be related to the generally greater size of the females compared to the males.

Both McDowall (1968b) and Pollard (1973a) give details of variations of diet of G. maculatus with season. McDowall relates these patterns partly to varied abundance of food items as does Pollard who also considered that changes in size of fish over the season may have some effect.

McDowall (1968b) found that peak feeding activity occurred during autumn. This is also the spawning time for this species, hence McDowall considered this to be a pre-breeding build up as guts of fishes from breeding shoals were found to be empty. Sloane (1976) found that the mean fullness index during a 24 hour sampling run was lowest during the late afternoon increasing throughout the night, indicating that feeding was spread throughout the night and early morning.

### 5.6.4. Life History.

This subject has received considerable study in G. maculatus so that it is now better documented for this species than any other freshwater fish found in Tasmania. However none of the major studies have taken place in Tasmania.

The life cycle of G. maculatus has two major phases; a marine juvenile stage followed by a period of growth in fresh water concluding with a return to the estuaries to spawn. As usual, little is known of the juvenile phase but the freshwater life has been closely studied. The migrations which commence and later terminate this stage are treated separately from growth

details during this phase.

The landlocked population of G. maculatus studied by Pollard (1971a) exhibited a change in the time of breeding from autumn as in riverine populations to late winter-early spring. This factor should be kept in mind when considering age and growth details for this population.

5.6.4.1. Age and growth.

The growth details are complicated by the fact that different authors have used different measuring techniques. The two most common being length to caudal fork, LCF, (eg. McDowall 1968b) and standard length, SL, (eg. Scott 1938; Woods 1968a). Woods (1968a) gives a conversion where mean LCF = 1.15 SL for G. maculatus.

McDowall (1968b) measured the length of 8,722 fresh-run whitebait in New Zealand and found that they varied from 37 to 62 mm LCF with a mean length of 52.5 mm. In an earlier paper McDowall (1964c) stated that the length for 1963 samples of G. maculatus collected in New Zealand was usually between 51 and 54 mm LCF. McDowall (1968b) also found some consistent variations in length of fish from different localities. Woods (1968a) observed size ranges of 45.0 to 47.1 mm SL (52-54mm LCF) for further New Zealand samples of G. maculatus and Benzie (1968b) found that her samples averaged 45 mm SL without significant seasonal variation. Scott (1938) made a series of biometric measurements on G. maculatus from Punchbowl Creek near Launceston,Tasmania. He found that juveniles which mainly arrived in October were on average approximately 40 mm SL (46 mm LCF using Woods conversion). Sloane (1976) measured

samples of G. maculatus from the Jordan River Tasmania and found that the smallest specimens he recorded were 60-65 mm total length (TL). However these specimens were not fresh-run fish but several months older than those of McDowall to which Sloane compared them. Also Sloane measured the longer TL character compared with McDowalls measurement of LCF.

Woods (1968a) found that the umpigmented fish which moved upstream in the early part of the season were larger than the later run fish. This factor was also partially supported by McDowall's (1968b) data. Woods (1968a) stated that there was an overall decrease in length of 25% before resumption of positive growth. He found that the change was not uniform over the whole body with the head only shrinking by about 15%.

Such a non-uniform growth pattern was not found by Scott (1938) but was reported on by Benzie (1968b) who studied closely the head length/standard length ratio and McDowall (1968b) found that after the stage at which these changes occurred (about 60 mm LCF) longitudinal growth measurements were then all isometric.

The age of the jolly-tail at the time of this inward migration is generally considered to be about six months (Woods 1968a; McDowall 1968b) however Stokell (1955) considered that this period was too short to enable such growth to occur and that the marine period was more likely 18 months or more. The findings of Pollard (1971a) indicate that the former is most likely as the larvae from his landlocked population grew to 60 mm in their first six months. Pollard makes no mention of the shrinkage observed by the authors quoted previously.

The analysis of growth of the adult fish is further complicated by the fact that spawning may occur to a reduced degree at times other than autumn thus giving rise to juveniles in the populations at various times of the year. Also the phenomenon of shrinkage before onset of adult growth greatly complicates the length frequency histograms (McDowall 1968b).

McDowall (1968b) does not give a break down of size in each of the year classes as they are unclear. However Burnet (1965) measured fish of known age captured on their spawning migration in a New Zealand stream and found that one year old fish averaged 73 and 83 mm in 1960 and 1962. Samples of 2 year old fish averaged 127 and 121 mm in 1961 and 1963 respectively.

Scott (1938) found that G. maculatus grew to an average of about 69 mm SL by the end of their first summer in Punchbowl Creek and averaged 86 mm by the end of the second summer. These lengths are smaller than those given by Burnet (1965) but larger than those of Benzie (1968b) who found that her samples averaged 56 mm SL at the end of their first year.

Pollard (1971a) found that fish in a landlocked population he studied reached average lengths of 90, 140 and 170 mm LCF after 1, 2 and 3 years respectively. Eldon (1969) raised G. maculatus in aquaria in New Zealand and found that they measured about 55 to 80 mm after 1 year and 110 mm or more after 2 years.

5.6.4.2. Size and longevity.

The largest size attained by this species is usually in the range 140-170 mm. McDowall (1968b) recorded it to 142 mm in his study and Pollard (1971a) measured the species to 175 mm. Scott (1938) reports on a specimen of 185 mm SL (203 mm LCF)

from a farm dam in northern Tasmania. Sloane (1976) measured specimens up to 170 mm from the Jordan River, Tasmania. Numerous other authors record the maximum length of the species somewhere within this range.

Most authors conclude that the majority of fish mature in their first year in freshwater (Scott 1938; Burnet 1965; McDowall 1968b; Woods 1968a; Eldon 1969; Pollard 1971a). These authors also record fish of an age up to 3+ years which have either not spawned or survived spawning. I have not seen records of any fish regarded as being older than three years and Benzie (1968d) considered that it was unlikely that G. maculatus would survive beyond this age.

5.6.4.3. Development of pigmentation.

G. maculatus are transparent with little apparent pigmentation on early arrival in freshwater apart from some xanthophores in mid dorsal rows along the trunk and some on the head and some melanophores as mid lateral and ventral lines (McDowall 1968b). Woods (1968a) considered the melanophore pigmentation diagnostic of the species. McDowall (1968b) found that pigmentation began to intensify soon after contact with freshwater. Both McDowall and Woods found that the pigmentation first intensifies on the dorsal surface and extends from there to the lateral surface. The pigmentation intensifies and becomes fragmented into a variable mottled pattern.

A guanine layer develops in the lining of the abdominal cavity and since the body wall of this species is translucent with little pigmentation this layer is easily seen (McDowall 1968b) and appears silver in fresh specimens.

Woods (1968a) found that the pigmentation of G. maculatus was different from most other galaxiids in that the melanophores are in the subcutis and not in the cutaneous layer. It is perhaps the least pigmented of all the galaxiid species.

5.6.4.4. Maturation, fecundity and sex ratio.

Benzie (1968b) found that sexual differentiation usually began at between 50 and 55 mm SL in the population she studied in New Zealand and that fish were sexually mature by the end of February. McDowall (1968b) stated that "The gonads of G. maculatus mature mostly in the late summer and autumn". McDowall found that fish developed virtually simultaneously in the estuary and upstream with a slight tendancy for the larger fish to develop earlier than the smaller ones. Burnet (1965) also suggested that second year spawners migrated downstream a little earlier. Benzie (1968a) suggested that the final maturation of G. maculatus was facilitated by their aggregation in the spawning area.

Pollard (1971a) found that gonad maturation of the land-locked population of G. maculatus began around March and continued rapidly until fully mature in June. The final maturity stage is attained after moving into the inflowing creeks. Pollard (1971b) gives details of changes in the gonosomatic ratio of G. maculatus over a seasonal cycle and in a later paper (Pollard 1972a) describes the macroscopic and histological development of the gonads of G. maculatus. In this paper he records a single case of hermaphroditism and he cites another record of this (Benzie 1961) for this species.

It is generally agreed by most authors that the majority of G. maculatus specimens mature at one year of age. Scott (1938) recorded that 78% of the specimens he examined were in their first year. Burnet (1965) found that almost all fish breeding in his study area were one year old and that only about 3% remained behind for a second year and even fewer for a third year. McDowall (1968b) agreed with these findings and showed that most fish in the breeding shoals were between 60 and 90 mm with females generally being slightly larger than males. This latter fact was also found by Pollard (1971a).

McDowall (1968b) found that the egg number for G. maculatus varied from 175 to 13,500 for fish between 43 and 135 mm LCF with a "fairly good relationship between egg number and fish size". He also found most variation among the larger fishes and also marked variation between localities. McDowall related this latter variation to differences in stream type. Campos (1970) found that the fecundity of G. maculatus he studied from Chile varied between about 300 and 7500 for fish between 45 and 160 mm in length.

McDowall (1968b) found that the sex ratio of this species varied from 0.2:1.0 (male:female) to 5.0 to 1.0. He found that the ratio in the breeding shoals varied within the above range but that there was normally a dominance of males in the estuarine areas.

Pollard (1971a) found that there was a greater proportion of male fish in the smaller size groups with the number of females being greatest in the larger size groups. After considering several biases in his data Pollard gives an overall ratio of 41:59 male:female for his landlocked population.

5.6.4.5. Migrations.

There are two major migrations in the life cycle of G. maculatus. The first involves the movement into freshwater from the sea and the second is a movement to the estuaries to breed. A further migration of returning adult fish is indicated by Phillips (1919) and Scott (1938) but it is not a well recorded one and was not observed by McDowall (1968b).

The initial movement into freshwater is of considerable importance commercially as it is at this time that the fish are captured and marketed as whitebait. The whitebait run has long been known but it was not always known that these fish were the young of the freshwater jollytail (see Hope 1928).

McDowall (1968b) observed that the main whitebait run in New Zealand began in July in the North Island and August in the South Island although he found that some individuals were migrating at all times of the year. The duration of the major part of the run was found to be from August to February by this author. Benzie (1968b) narrows the major run down to September to November which she states is the official season. The data for McDowall's (1965) paper on the composition of the New Zealand whitebait catch were also collected during this period.

Records of the G. maculatus run in Tasmania can be ascertained from the whitebait fishery data in the Annual Reports of the Tasmanian Inland Fisheries Commission (see Lynch 1966-1973). These show that G. maculatus was captured largely in the months of September and October with some isolated catches in August. Scott (1938) stated that there was

"an extensive juvenile influx in October, followed by a less important immigration in March" into the Tasmanian creek he studied.

Benzie (1968b) reports that from data supplied to her there was no correlation between the G. maculatus runs and either river temperature or the peak tides. However there was evidence of correlation between sudden rises in river level and peak runs. Benzie considered that such flushes served to allow penetration of freshwater further out to sea.

Phillips (1924a) also noted that the whitebait ascended New Zealand streams after an increase in river level. Pollard (1971a) found that a juvenile migration was lacking in the landlocked population of G. maculatus in Victoria.

The second major migration involves the movement of fish to the spawning sites. Burnet (1965) trapped mature fish migrating downstream mainly in February and March with some in April and May. This migration time is recorded by numerous earlier authors from New Zealand (eg. Sherrin 1886; Clarke 1899; McKenzie 1904; Phillips 1919, 1924a) and Scott (1938) records that adults move downstream in Tasmania in April.

Burnet (1965) found that the downstream movement was at either the full moon or spring tide peak. He found that the migrations were not related to other climatic factors such as rainfall. Benzie (1968a) concluded from her data and that of Burnet that "sexually mature G. m. attenuatus migrate down stream at the phase of the moon appropriate to the nearest spring tide." McDowall (1968b) observed that fish migrated downstream during daylight but found no records of nocturnal

migration.

The landlocked population studied by Pollard (1971b) was observed to undergo a short spawning migration from July to October with a peak in August-September. The direction of migration is also reversed in this case as fish move a short distance into the inflowing streams of the lake. Pollard (1971b) considered that increased stream discharge was the factor which stimulated the spawning migration of the landlocked jollytail.

In regard to a possible third migration, i.e. of returning adult fish, Clarke (1809) reported that New Zealand G. maculatus returned upstream in March, April and May and Phillips (1919) reported that the adults in a "thin and light condition" returned upstream in June, July and August. Scott (1938) stated that fish returned after spawning in July in the Tasmanian stream he studied. McDowall (1968b) did not find any evidence of this migration in his survey and stated that later workers had not found support for Clarkes comments. This subject warrants further scrutiny.

5.6.4.6. Breeding biology.

5.6.4.6.1. Spawning site.

The spawning site of G. maculatus was a contentious issue in early New Zealand literature. Hutton (1872) considered that the species spawned in the sea and this theory was adhered to by Clarke (1899), Sherrin (1886), Regan (1915), McCulloch (1919) and Phillipps (1919), to name a few. There were some who did not agree that the species spawned in the sea (eg. McKenzie 1904; Meek 1916) and Maori reports of a non-marine spawning site quoted in Phillipps (1919) were refuted

by that author. In a later paper, Phillipps (1924a) records several reports supplied to him (probably in response to his earlier paper) of G. maculatus spawning near river mouths. This spawning site had also been earlier reported in New Zealand by McKenzie (1904). Later authors such as Hayes (see Hefford 1931a,b, 1932), Benzie (1968a), McDowall (1968b) and Pollard (1971a) have also discovered the spawning site and have fully documented their findings. The reasons for the choice of a certain spawning site are unclear but the areas are summarised by McDowall (1968b) as follows "Galaxias maculatus spawns in tidal estuaries either in salty or fresh-water, but usually in areas affected by upstream tidal push." The eggs were deposited amongst vegetation which was covered by high tides at the margins of the river (Benzie 1968a). The area is further defined by Hayes (Hefford 1931a) as "among the herbage on the banks of the estuary above the level of high water of ordinary tides. The vegetation type selected was found by the authors to be variable from grass clover pasture (Benzie 1968a; McDowall 1968b) to sedges and rushes (Hayes in Hefford 1931a,b, 1932).

The spawning site of landlocked G. maculatus was si arly reported by Pollard (1971a) as being amongst vegetation along the margins of flooded creeks flowing into the lake he studied.

5.6.4.6.2 Spawning behaviour and time.

McDowall (1968b) observed that the species often formed very large compact and closely coordinated shoals as the spawning time approached. He noted that these shoals gave the impression that they were searching the banks of the stream for a suitable spawning site.

Benzie (1968a) found that all of the fish move into the spawning area together which generally appeared to occur when

the tide was beginning to fall whence the depth of water was barely enough to cover the fish. Spawning appeared to be communal with no evidence of male-female pairing. This fact was further indicated by the variation of the sex ratio of spawning shoals from month to month (Benzie 1968a).

On the actual spawning Benzie (1968a) noted that "Each female sheds all her eggs in a short series of abdominal contractions associated with a lateral swish of the tail. The males shed their milt and in the disturbance it is spread so that the whole area of the water over the shoal looks milky." This milky colouration of the water was also noted by McKenzie (1904) and Phillipps (1924a) noted that the species was sometimes called cowfish because of the colour produced by the milt.

Benzie (1968a) found that spawning began from one to three days after the new moon or full moon in the years she studied. In these years the spring tides were associated with these lunar phases. The data of Hayes as examined by Benzie (1968a) show that spawning time correlated with the full or new moon but for some of these times there was not a complete correlation with the spring tides.

Hayes (in Hefford 1931a) and Benzie (1968a) showed that spawning continued for up to three days after its commencement which was usually about one to three days after the appropriate moon phase. Benzie further showed that spawning took place on both the morning and evening tides during this period. The spawning process was then usually repeated when conditions were again met which was generally a fortnight or a month later and could take place throughout most of the year although it mainly occurred from about March to May (McDowall 1968b).

Whilst the riverine populations of G. maculatus use the high tides for spawning the landlocked population studied by Pollard (1971a) used the flooding of streams in a similar manner. Pollard, in relating the two habitats, stated that "the eggs being deposited in slow-flowing water over similar, shallow, flat, flooded areas amongst the vegetation along the stream banks, and also remaining stranded when the water subsides."

As found by Pollard for the landlocked form the ova of riverine populations are left adhering to the vegetation at the rivers edge after the tide recedes. They then require a later high tide to cover the ground whereupon hatching rapidly takes place (Benzie 1968a). The next high spring tide usually occurs after two weeks but may be later and hatching can be delayed for a considerable time.

5.6.4.6.3. Fate of spawners.

As indicated above some authors have noted an upstream migration of adult fish but none of these fish were examined to determine whether they had spawned or not. McDowall (1968b) found few fish (5 females) which had survived spawning and had recovering gonads, but they were generally in poor condition. McDowall concluded that "G. maculatus does not usually survive breeding, although a few fish may do so". McDowall did not however observe the death of the spawners.

Pollard (1971a) found "that although many of the spent fish die after spawning, a number survive and return to the lake."

5.6.4.7. Embryology and development.

The unspawned eggs of the jollytail were found to be roughly spherical and almost colourless (McDowall 1968b) with a diameter of approximately 1.0 mm (Benzie 1968c; McDowall 1968b).

The spawned but unfertilized egg was found to be slightly sticky and vary in size between 0.9 and 1.4 mm in diameter with no relationship being found between egg diameter and fish size by McDowall (1968b). He also found that the stickiness was retained by the unfertilised eggs but was lost by fertilised eggs. Benzie (1968c) gave the diameter of the fertilised egg as about 1.2 mm. McDowall (1968b) considered that this loss of stickiness after fertilisation would allow the eggs to drop further down among the stream bank vegetation where conditions were presumably better for development.

Benzie (1968c) found that naturally spawned eggs were exposed to temperatures between 5 and 18°C in the area she studied but no abnormalities and only low mortalities were observed. She found that the mortality rate of artificially fertilised eggs was much higher however.

Benzie (1968c) describes the sequence of development from egg to embryo of G. maculatus which she breaks into 22 stages culminating in a stage at which the embryo can hatch when immersed in water. The stages are described and diagrams of each are given by Benzie (1968c). She followed the development of the eggs at 17 and 4.4°C and found a marked difference in the time taken to reach full development. Eggs at the higher temperature were capable of hatching after 10 days compared with 31 days at 4.4°C. Benzie showed that field temperatures were seldom (if ever) constantly this high and under the best conditions she observed development took 14-16 days. Therefore although some of the fish may hatch on the following spring tides many would have to wait for the second series of tides after spawning.

Benzie (1968a,c) and McDowall (1968b) both found that the eggs were capable of hatching after only 10 minutes immersion in either fresh or salt water or a mixture of the two. McDowall further found that not all the eggs hatched so readily and that they continued to hatch for more than two weeks after their initial immersion. He also found, as did Hayes (in Hefford 1931a), that the eggs can survive for at least two months and still hatch successfully. Campos (1970) studied the embryology of G. maculatus in Chile and found the details to be similar to those given by Benzie for New Zealand G. maculatus. Pollard (1971a) also concluded that "the pattern of extra-aquatic development, delayed hatching, and flooding as the hatching stimulus, appears to be very similar, if not identical, in both G. maculatus and the landlocked jollytail."

At hatching the larvae measured about 7 mm in length (Benzie 1968c; McDowall 1968b; Pollard 1971a) and this stage is figured by the first two authors quoted above. Benzie (1968a) found that "The young hatch and swim up towards the light and swim together as if schooling." She qualifies this by saying that, "the 'schooling' response is only a reaction to current!" The larvae are then taken to sea by the receding tide (Benzie 1968a), or washed downstream into the lake in the case reported by Pollard (1971a). McDowall (1968b) thought that the larvae could be reared artificially in sea water. He succeeded in rearing them to a length of 15 mm but at a much slower growth rate than the expected natural rate.

Further details of larval development are unknown, as they occur in the sea. However Pollard (1971a) found that the landlocked juveniles took shelter amongst vegetation

at the margin of the lake. Pollard found larval growth was faster and that the onset of adult pigmentation was earlier in this population compared with the riverine fish.

5.6.5 Anatomy, Histology and Ultrastructure.

Some details of anatomical changes observed during development of G. maculatus are given by Benzie (1968a,c) McDowall (1968b) and Woods (1968a). Morphometric and meristic variations in this species are given by numerous authors. South American specimens were examined by McDowall (1971b) and this author (McDowall 1970c) also gives data on New Zealand material. Mainland Australian material from a landlocked population was examined by Pollard (1971b, 1972a). Tasmanian specimens have been examined by Scott (1938), Stokell (1966) and Andrews (1976). McDowall (1972b) brought together most of the available data on this subject from South America, Australia and New Zealand. Aspects of the osteology of G. maculatus were closely studied by Swinnerton (1901) and more recently several other authors have studied some aspects of the osteology of the species (Frankenberg 1969; Rosen 1974; Andrews 1976).

The gross anatomy of the brain of G. maculatus was briefly studied by Boyle (1975) and Cadwallader (1975a). Both these authors attempted to relate the structure of this organ to the habitat of the species. Boyle further studied the anatomy of the olfactory organ, parts of which were found to be unusual in structure.

The histology of the olfactory epithelia was studied using scanning and transmission electron microscopy as well as light microscopy techniques by Boyle (1975). She also studied the effects of various sub-lethal levels of cadmium on the histology of these tissues at the light microscope level.

The histology of the ovaries and testes of G. maculatus was

studied by Pollard (1972a) during various stages of development. Pollard was able to approximately relate the seven arbitrary maturity stages he used in a previous paper (Pollard 1971b) to seven histological stages in testicular development.

Campos (1972) studied the karyology of G. maculatus from Victoria and landlocked and catadromous populations from Chile. He found marked similarities in the karyotypes with a diploid number of 22. He considered this to be further strong evidence that geographically separate populations of this fish are conspecific.

5.6.6 Physiology.

Chessman and Williams (1975) found that G. maculatus is able to both hypo- and hyper- osmoregulate within the salinity range of its normal habitat. They found it naturally in salinities of less than 1ppt to 49ppt. The upper LD 50 for salinity was found to be 62ppt after gradual acclimation and 45ppt after direct exposure.

Cassidy (1974) and Cassidy and Lake (1975) give details of the effects of cadmium on G. maculatus. They found that the L.C. 50 level varies from 1.3 to 10.3ppm and that increased temperature increases the lethal effect of cadmium. Cassidy (1974) also found that sublethal levels of cadmium have marked effects on schooling behaviour, and there is no avoidance reaction to quite low doses and that feeding is inhibited after short exposure to low concentrations of cadmium. He considered that the cadmium probably causes damage to the chemoreceptor system. This theory was substantiated by Boyle (1975) who found that sublethal doses of cadmium cause reversible damage

to the olfactory epithelia in G. maculatus.

5.6.7 Diseases, Parasites and Natural Predation.

No diseases have been recorded for G. maculatus although Boyle (1975) found that specimens kept in aquaria were prone to fungal attack.

Pollard (1973b) records two parasites common in landlocked G. maculatus in Victoria. The first of these was the plerocercoid stage of a cestode of the genus Ligula. He found that the infection rate was about 50% and that infection caused a reduction in general body condition and inhibition of gonadal maturation and reproductive migration. The second parasite, found in about 80% of the fish studied by Pollard, was the nematode Eustrongylides c.f. gadopsis. This nematode along with a Contracaecum sp. is also recorded in G. maculatus from South Australia (Johnston & Mawson 1940, 1944). Pollard (1973b) found that E. gadopsis caused inhibition of egg laying when encysted in the ovary or vent.

Numerous other parasites have been recorded from G. maculatus in New Zealand. Acanthocephalus sp. was recorded by McFarlane (1939) Manter (1954) and McDowall (1968b). The latter author found that these parasites were in such large numbers in some cases that they appeared to block the gut canal. Hine (1977a) described this species as A. galaxii.

A sporozoan parasite, Myxobulus iucundus, was described from G. maculatus in New Zealand by Hine (1977c) and a species similar to this has been found from this fish in Tasmania. (Sloane pers. comm.).

Several trematode parasites of G. maculatus in New Zealand have also been described. Coitocaecum anaspidis was found in the intestine by McFarlane (1939). Deretrema minutum was also found in the intestine by Manter (1954) and McDowall (1968) and Telogaster opisthorchis was found encysted in the muscles by McFarlane (1945, 1952). Another species of trematode Coitocaecum parvum was recorded from Tasmanian G. maculatus by Crowcroft (1945).

Hewitt and Hine (1972) record four species of nematodes from G. maculatus in New Zealand all of which were recorded by McDowall (1968b) and some by other earlier authors. Other nematode species from Australian G. maculatus are mentioned above. Also found in New Zealand G. maculatus is a species of cestode parasite which was noted by McDowall (1968b) and later identified as Nippotaenia contorta by Hine (1977b).

In regard to natural predators of G. maculatus there appears to be little information. Blackburn (1950) lists several species of fish and birds as predators of the Tasmanian whitebait Lovettia sealii and it is likely that many of these are also predators of G. maculatus. Paddon (1947) stated that brown trout prefer Galaxias to Lovettia! Wether the Tasmanian trout are quite so discerning has not been proven but several New Zealand authors in particular have remarked on the use and value of G. maculatus as a trout food (Hamilton 1904; Hope 1928; Phillips 1929; Sapsworth 1945).

5.6.8 Competition.

No details have been published on interspecific competition in this species and it is doubtful if any such

interaction exists. No detailed information is available in relation to other species either. Phillips (1929) intimates that there may be some overlap in the diets of trout and G. maculatus and the Australian findings of Butcher (1945) Sloane (1976) and Lake and Bennison (1977) indicate that this is so, however, none of these later authors positively conclude that competition exists.

Ferguson (1888) conducted some aquarium tests in New Zealand in which he found that G. maculatus would devour trout fry placed in with them. He then concluded that this was the cause of the disappearance of young trout from New Zealand streams. Such would doubtless be the behaviour of most of our freshwater fish if presented with such an easy prey within the confines of an aquarium.

There does not seem to be any other native or any introduced fish species which competes seriously with G. maculatus however man's activities are of some concern. Several New Zealand authors remarked on the need for care in exploitation of that countries whitebait stocks right from the early stages of the industry (Clarke 1899; Hope 1928; Hefford 1937; Phillipps 1940; Stokell 1955; McDowall 1968b). The Tasmanian whitebait fishery has also undergone a serious decline (see section on Lovettia sealii). The major bulk of this fishery was for L. sealii but G. maculatus was also included in the catch and it appears that stocks of this fish have also declined.

McDowall (1976b) indicated the importance of New Zealand's estuaries in the life cycle of various fishes and the need to keep them free of pollution and habitat changes but he does not fully elaborate on the importance of this site for breeding

in G. maculatus. In an earlier paper McDowall (1975) warned on the dangers to many species of fish (including G. maculatus) from programs of reclamation and swamp drainage. Tasmanias estuaries are much more extensive than those of New Zealand and many are industrialised and undergoing serious habitat alteration, however, no attempt has ever been made in Tasmania to gauge the effects of these changes on G. maculatus or any other fish.

5.6.9 Use as food.

G. maculatus has been long valued as a food by the Maori people of New Zealand and records of this use are given by various authors (Hutton 1872; Hector 1872; Sherrin 1886; Fletcher 1918; Best 1929; Phillips 1940; Graham 1953; Firth 1959). G. maculatus is the principal species in the important commercial whitebait fishery in New Zealand, which was first reported on by Hector (1872) and later by Hector (1883) Reid (1886) and Clarke (1899). The latter author wrote of the export of dried whitebait by Chinese from New Zealand and of the extensive use of the fish as a fertiliser.

The decline in the New Zealand fishery is reported by McDowall (1968b) and numerous possible causes given including habitat destruction in various forms, pollution and early over-exploitation of stocks. The most useful present day fishing areas are those of the relatively undisturbed West Coast rivers of New Zealand (McDowall 1968b).

The Tasmanian commercial whitebait fishery was largely concentrated on Lovettia sealii but G. maculatus also formed a considerable part of the catch as evidenced by the production

figures for the fishery (see Lynch 1965 to 1975). There is evidence of a decline in the proportion of L. sealii to other whitebait species in the catches (Blackburn 1950; Lynch 1965) but it is not clear if the numbers of G. maculatus were also declining or remaining constant whilst Lovettia dissappeared. However, since the total whitebait catch dropped to a level where commercial operations had to be ceased the former is probably the case with G. maculatus also.

The recreational value of the Tasmanian whitebait fishery has not been documented but it was of considerable value when stocks were plentiful.

5.7 Galaxias parvus.

G. parvus is one of the smaller endemic galaxiid species and was described in 1968 (Frankenberg 1968). It had been collected by two parties of Victorian biologists during trips to the Lake Pedder region before a collection was made by Frankenberg for the species description.

It was found in Lake Pedder and the headwaters of the Huon and Serpentine Rivers (Frankenberg 1968). Andrews (1976) recorded the species from these localities and also from a tributary of the Wedge River. The species is now present in the flooded Lake Pedder and probably also in Lake Gordon.

G. parvus was found in still pools, swamps and backwaters and in open shallow water at the edge of the original Lake Pedder (Frankenberg 1968). It is one of the smaller species of galaxiids. The maximum size observed by Frankenberg (1968) was 54 mm SL and by Andrews (1976) was 75 mm SL.

The life history of this species has not been studied in any detail. Frankenberg (1968) found immature gonad development in ten specimens collected during February-March. Andrews (1976) made similar observations and he postulated a winter spawning period.

At the time of the flooding of Lake Pedder fears were held for the survival of G. parvus in the new environment. The species has survived and appears to be doing well in the new lake to date, although it is not as numerous as G. pedderensis.

5.8 Galaxias pedderensis; (Pedder galaxias).

This is the second of the two species of galaxiids confined to the Lake Pedder region of south west Tasmania. It was also described by Frankenberg in 1968.

Frankenberg (1968) gives its distribution as "Lake Pedder and immediate surrounds." Andrews (1976) found it also in tributaries of the upper Serpentine and Wedge Rivers. From my collecting in the area I have found this species to be plentiful in a riverine environment as well as being common in Lake Pedder. Hence it may now spread to many of the rivers flowing into Lake Gordon as well as Lake Pedder tributaries.

Frankenberg (1968) found that the largest specimen he observed was 70 mm SL whilst Andrews (1976) collected a specimen 97 mm SL. The mean SL of twenty specimens I measured was 73 mm and the maximum SL was 95 mm.

Specimens collected by Frankenberg (1968) were found to have immature gonads. Andrews (1976) reports similar findings but he also records females with almost fully developed eggs in late March. Andrews thought that a late autumn or winter

spawning period was likely. He also found mature females congregating below a stream barrier and from this postulated an upstream migration and a spawning site in the upper reaches of streams. However more concrete evidence is required to justify these conclusions.

Andrews (1976) also reports that large numbers of juvenile G. pedderensis have been seen around the edges of Lake Pedder during December-March. This sight is now common in the flooded Lake Pedder and the schools reach large proportions. Schooling at this time of the year would probably indicate a late winter spawning time for this species.

As with G. parvus, there were some doubts as to the ability of G. pedderensis to survive the flooding of Lake Pedder. However it is now extremely prolific and appears to be forming a major part of the diet of the large brown trout of Lake Pedder.

5.9 Galaxias tanycephalus; (narrow-headed galaxias).

As with G. auratus (Frankenberg 1974; Andrews 1976) this species is probably a landlocked derivitive of G. truttaceus (Fulton 1978a). It is another endemic species and was first collected in 1976 and described in 1978 (Fulton 1978a).

It has been collected from Arthurs Lake, Woods Lake and from the Lake River just below Woods Lake (Fulton 1978a). The lacustrine habitat of the species has not been detailed and it is not known if it enters streams flowing into Arthurs or Woods Lakes. Fulton recorded the species up to a maximum size of 147 mm TL which places it about the middle of the size range exhibited by Galaxias in Tasmania.

The life history of G. tanycephalus has not received any detailed study. Fulton (1978a) collected specimens with mature ovaries in early October thus indicating a late winter-early spring spawning time.

This species is not common anywhere within its range and several efforts to recollect it since the collections listed by Fulton have met with limited success. Further collecting could prove that it is more numerous but it is unlikely and some effort should now be made to investigate the species more closely and afford it some protection.

5.10 Galaxias truttaceus; (spotted galaxias).

Also often called the spotted mountain trout this species is one of the most striking of all the galaxiids. It was the first species described from Tasmania (Valenciennes, in Cuvier & Valenciennes 1846) and is one of the most common and widespread species in the state.

In his major contribution to Tasmanian ichthology Johnston obviously did not appreciate the differences between this species and G. brevipinnis (Johnston 1883) nor did Whitley in his coverage of Johnston's original notes (Whitley 1929a). Hence the range of habitat occupied and variety of colour exhibited for G. truttaceus given by these two authors in the above papers could be somewhat confusing to later readers. The most up to date and clear description of the species is given by Andrews (1976) and further morphometric and meristic data are given by Fulton (1978a).

5.10.1 Distribution within the state.

As indicated above G. truttaceus is one of the most widely distributed species in Tasmania. The recent maps of Frankenberg (1974) and Andrews (1976) illustrate this. Apart from the lower reaches of most of the states rivers it is also found in some lakes, particularly those to the west of Great Lake in the central plateau area, and also on King Island and the Furneaux group in Bass Strait.

In the streams G. truttaceus appears to be confined to the coastal areas (Andrews 1973, 1976) although it probably penetrates further upstream than G. maculatus (see section above).

5.10.2 Habitat.

A variation in the normal habitat of galaxiids was reported in "The Mercury" of July 23 1974. Specimens identifiable with G. truttaceus, (but lacking the characteristic body spots), were collected from a cave in southern Tasmania (Anon. 1974). Further details of this record are given by Andrews (1976). Although this is not the most usual habitat of G. truttaceus the lack of pigment and apparent lack of sight reported by Andrews (1976) indicate that the population had occupied the cave for some considerable time.

Both Frankenberg (1969, 1974) and Andrews (1976) found that the species is common in coastal streams as was earlier found by Scott (1941) who further noted that there was a wide range in the salinity of collection sites from salt or highly brackish waters to fresh waters. Scott (1941) also examined the salinity tolerance of G. truttaceus and found that it could withstand changes from fresh to salt without any apparent ill-effects.

The specific habitat preferred in stream or lake has not been detailed. It certainly differs from that of G. maculatus where their ranges overlap in that G. truttaceus does not appear to form schools or aggregate and is usually much more secretive than G. maculatus.

5.10.3 Life History

Although G. truttaceus is one of the states most common freshwater fishes, few details are known of its life history. No details are known of its food or feeding behaviour either.

Scott (1936a) observed that it was a constituent of the Tasmanian whitebait runs. He further studied the species in Punchbowl Creek (Scott 1941) a small stream near Launceston in northern Tasmania. Scott found that there was usually a migration of juvenile fish into the stream in the October-December period of each year. This migration time is further noted and extended to include September in the whitebait catch statistics for Tasmania (Lynch 1965, 1966, 1968, 1969, 1970, 1971) and from data from catch records of an upstream fish trap on the Plenty River, southern Tasmania (Fulton & Sloane unpublished).

Scott (1941) gives the mean standard lengths of the immigrants as 46.66 and 47.51 mm for the years 1935 and 1938 respectively (79 and 39 specimens measured). Scott (1941) was of the opinion that a second, less marked, migration of smaller juvenile fish occurred during February-March. Such a migration was not observed in the Plenty River (Fulton & Sloane unpublished).

As is found in other whitebait species (McDowall 1968b, 1970c; Woods 1968a) G. truttaceus undergoes changes in pigmentation from the unpigmented early whitebait stage through to the spotted adult stage (Scott 1941). The unpatterned stage is folowed by a barred pattern with the adult spotted pigmentation not being fully developed until the fish were more than 98 mm SL in the population studied by Scott (1941). Numerous stages between the three major phases were recognised by Scott, as were variations in the adult colour pattern.

The age structure of G. truttaceus populations is not known but from Scott's (1941) data it appears that it may reach a length of about 70 mm SL after their first year. It may probably live for three years or more as Andrews (1976) recorded specimens up to 172 mm SL.

Breeding has not been observed in this species. Scott (1941) suggested that it may descend to brackish water or the sea to breed. Frankenberg (1974) also considered that G. truttaceus probably descend streams to spawn. A similar New Zealand species (McDowall 1970), G. fasciatus, has been found to breed in streams with the young being washed to sea (Ots & Eldon 1975) and later returning in the whitebait runs (McDowall 1964b, 1965; Woods 1968). The breeding site of lacustrine G. truttaceus is also entirely unknown.

Riverine populations probably breed in Autumn (Scott 1941; Andrews 1976) but, as with other lacustrine galaxiids, such populations probably do not breed until Spring (Andrews 1976). Limited data on fecundity is given by Scott (1941) who found that a specimen of 113 mm SL contained "5643 ova, with a modal diameter (in formalin) of 1.0-1.3 mm."

5.10.4 Natural Predation and Competition.

Apart from the natural predators of the 'whitebait' as listed by Blackburn (1950) no details of predation or competition involving G. truttaceus have been published. G. truttaceus, as stated above, is widely distributed in Tasmania and is also quite common throughout its range. It does not appear to be in any danger of extinction to date.

It has long been appreciated that it is an excellent table fish as an adult (Richardson 1848; Johnston 1891, 1914). The latter author records that it was readily caught by rod and line. Nowadays it is not generally used for food as an adult but it is common in whitebait catches in Tasmania (Lynch 1965a; Anon 1968a). From the catch details for the Tasmanian whitebait fishery (Lynch 1965-1974) it is seen that G. truttaceus formed an important part of the whitebait catch and was third in order of importance to Lovettia sealii and G. maculatus. This industry is no longer commercially viable hence G. truttaceus is no longer used for food to any great extent.

5.11 Galaxiella pusilla; (dwarf galaxias).

This diminutive species was first described from Victoria (Mack 1936) from specimens collected by an aquarium enthusiast (Mascola 1938). The first record of its occurrence in Tasmania appears to be Scott's (1966) reference to an undescribed Tasmanian form of Brachygalaxias.

Frankenberg (1966) also refers to its discovery in Tasmania but does not say from where or by whom. Scott (1971b) later described the Tasmanian forms as two subspecies of the mainland species. It received further attention from Andrews

(1976) who gives an adequate description and drops subspecific separation, and finally McDowall (1978b) who placed it in its present position in the new genus Galaxiella along with two similar Western Australian species. McDowall (1978b) gives detailed morphometric and meristic data for all three species.

5.11.1 Distribution within the State.

The distribution maps for this species given by Frankenberg (1974) and Andrews (1976) show only three sites in north-eastern Tasmania and Flinders Island. As remarked by Andrews (1976) further collection in the north-east could extend the range of the species.

5.11.2 Habitat.

Frankenberg (1974) states that G. pusilla is "adapted to still, confined, water bodies." The original specimens were collected from a swamp at the edge of a stream in Victoria (Massola 1938), whilst Tasmanian specimens were collected from "a soak from a dam". The closely related species, G. nigrostriatus was collected from similar sites in Western Australia (Shipway 1953). G. pusilla is apparently seldom found in fast flowing water and its habitat is probably essentially similar to that of the pygmy perch, Nannoperca australis (see Llewellyn 1974) with which it is often associated (Frankenberg 1967).

Backhouse and Vanner (1978) describe the habitat of this species in Victoria as follows "The dwarf galaxiid is typically found in still waters such as swamps, drains and backwaters of creeks and streams. The waters are usually shallow, often less than 30 cm deep and have abundant aquatic

vegetation. In larger pools the galaxiid is usually captured in the marginal vegetation surrounding the edge of the pool.

The waters inhabited by the galaxiid are often temporary, drying up partially or completely during summer, and being replenished by rainfall or floodwaters from a watercourse during the wetter months."

5.11.3 Life History.

G. pusilla is the smallest galaxiid found in Tasmania. Specimens up to 31.3 mm SL from Tasmania (Scott 1971b) and 40.3 mm TL from Victoria (Backhouse & Vanner 1978) have been recorded.

Some aspects of non-breeding behaviour of G. pusilla were observed by Backhouse and Vanner (1978). They noted that adult fish were not seen during the day but that juvenile fish were often seen in weed free surface waters. Although they appeared in groups there was no evidence of schooling behaviour. In aquaria the fish appeared to prefer the lower parts and rarely approached the surface. Schooling was not evident and there was little or no intraspecific aggression.

G. pusilla is the only Australian galaxiid which has been seen to breed in aquaria. This was accomplished by a member of the Aquarium Society of Victoria and details were recorded by its original collector (Massola 1938). Spawning in aquaria has also been observed more recently by Backhouse and Vanner (1978).

Observations were made of courtship behaviour and egg laying which was recorded in August (Massola 1938; Backhouse and Vanner 1978) and also in April (Backhouse

& Vanner 1978). It was found that the first indication of spawning was "when the male gently nudged the jugular and abdominal regions of a female." Several males at times displayed to one female in this manner (Backhouse & Vanner 1978). Both the above papers record that eggs were layed individually and were deposited on stones and leaves. After each egg had been laid the fish paid no further attention to it and there was no apparent pair bond formed as the male then turned his attention to any other female which was ready to spawn (Backhouse & Vanner 1978).

The female died after spawning (Massola 1938) but it is not known if this always occurs naturally. The eyed stage was visible after 5-6 days (Backhouse & Vanner 1978) and the eggs took 10-16 days to hatch after which the parents did not appear to tend the young in any way (Massola 1938; Backhouse & Vanner 1978).

In their natural habitat both gravid females and larval fish were observed together from late July to early September (Backhouse & Vanner 1978). These authors found that a sample of larvae measured 4.2 - 4.8 mm in length and that they swam to the surface and remained there after 1-2 days. The yolk sac was fully absorbed after 3 days.

Egg diameter ranged from 0.7 - 0.8 mm (unfertilized) and was 1.1 - 1.3 mm for fertilized eggs. Mature females were observed to contain 155-197 eggs.

McDowall (1978c) and Backhouse and Vanner (1978) found G. pusilla to be the only species of galaxiid showing sexual dimorphism. They found differences in overall size, some body proportions, the ventral keel and genital papillae and in colour between male and female fish.

G. pusilla is of no interest as a sport or food fish but could be of particular interest as an aquarium fish. It can be easily maintained in aquaria, is small, and is very attractive with its red and black striped colour pattern.

## 5.12 *Paragalaxias* species.

As outlined in the taxonomy section *P. dissimillis* was first positively collected from Tasmania by E.O.G. Scott in 1933 and described as *P. shannonensis* (Scott 1935a). It has not been closely investigated until very recently when further collections in Great Lake and neighbouring lakes have extended its known distribution and revealed the presence of three new species in the genus (McDowall & Fulton 1978a,b). So little is known of the biology of these species that they do not warrant individual treatment in this work.

It is obvious from the literature that, as well as indecision on the status of the genus *Paragalaxias* (Whitley 1935; Stokell 1945, 1950), several authors had overlooked the second species of *Paragalaxias* recently described from Great Lake (McDowall & Fulton 1978a). Stokell (1950), Whitley (1960) and Andrews (1976) have all included photographs of *P.eleotroides* for *P. dissimilis* in their respective papers.

### 5.12.1 Distribution within the State.

McDowall and Fulton (1978a,b) give distribution data for the four species. *P. dissimilis* occurs in Great Lake, Shannon Lagoon and Penstock Lagoon but not in Arthurs Lake as stated by Scott (1966) and repeated by Frankenberg (1974) and Andrews (1976). The species in Arthurs Lake is *P. mesotes* and this also occurs in Woods Lake and upper parts of the Lake River (McDowall & Fulton 1978a). Another species, *P. eleotroides*, is found in Great Lake and Shannon Lagoon (McDowall & Fulton 1978a) and probably also in Penstock Lagoon. The fourth species in the genus, *P. julianus*, is present in a number of lakes and

tarns to the west of Great Lake collectively referred to as "The Western Lakes". McDowall and Fulton (1978b) record this species from Lake Field, Lake Dudley and the Julian Lakes. I have since collected the species from Carter Lakes, Lake Baillie, Lake Ada, Ada Lagoon and Talinah Lagoon. Further investigation of the distribution of this genus is required.

5.12.2 Habitat.

Andrews (1973) found Paragalaxias very difficult to collect and he expressed the opinion that the species was not plentiful. However the use of electrofishing equipment in Great Lake revealed that both the species inhabiting that lake were quite abundant around the shoreline. P. dissimilis and P. eleotroides were not found in any streams flowing into Great Lake (McDowall & Fulton 1978a) except for some taken in a short section of stream connecting Great Lake and Shannon Lagoon (Scott 1935a). Both species are normally found amongst rocks around the shoreline of lakes often in very shallow water, also from amongst vegetation both living and dead and from under and in other debris (McDowall & Fulton 1978a).

P. mesotes was collected from construction site rock piles in Arthurs Lake (McDowall & Fulton 1978a) and from natural rock piles in this lake and in Woods Lake and the Lake River. It did not usually shelter in aquatic vegetation which bordered many of these rockpiles.

P. julianus was also collected from amongst and beneath rocks in the Western Lakes (McDowall & Fulton 1978b). These authors further note that the species appeared to prefer the cover of rocks "lying spaced apart on a gravelly substrate" and that P. julianus "was less common amongst piles of rocks.

5.12.3 Life History.

There are few published details on the life history of any of the species of Paragalaxias. Andrews (1976) quoted data which appeared to indicate a summer spawning time for P. dissimilis. Andrews also indicates that there is probably no spawning migration or juvenile adult metamorphosis in this species (personal communication from W. Fulton).

Age and growth details are not available either but McDowall and Fulton (1978a,b) give morphometric and meristic details as well as maximum and average lengths recorded for each of the four species.

5.12.4 Behaviour.

McDowall and Fulton (1978a) briefly noted the behaviour of the two Great Lake species, P. dissimilis and P. eleotroides in aquaria. They found that the latter species was almost always benthic in habit whereas P. dissimilis was observed more frequently swimming clear of the bottom. This behaviour has probably resulted due to competition between the two species during their evolution.

5.12.5 Diseases, Parasites, Natural Predation and Competition.

No diseases or parasites have been documented for any Paragalaxias species, however, P. julianus in particular is susceptible to a trematode metacercarial infection.

Similarly there are no published records of natural predation upon these species but I have seen specimens of a Paragalaxias species taken from the stomach of a tiger snake at Great Lake but I do not see this as a major predator of Paragalaxias.

The effects of competition on any of the four species have not been studied either but there is considerable scope for such study particularly in relation to trout but also between Paragalaxias and Galaxias species.

# CHAPTER 6 OTHER SALMONIFORM FISHES.

As mentioned earlier there are three non-galaxiid salmoniform fishes in three separate families present in Tasmania. The first of these to be considered below is the whitebait Lovettia sealii, which is the smallest species of the three and, next to the eel, probably the most commercially valuable native fish in the state. It is perhaps "lucky" to be considered as a freshwater fish at all as the species rarely goes into the river proper and is only found in the upper estuaries during the breeding season. The remaining two species, which may easily be confused with each other at certain stages, are the grayling Prototroctes maraena and the smelt Retropinna tasmanica.

## 6.1 Lovettia sealii; (whitebait)

In other countries when one refers to whitebait they do not mean L. sealii as this species is confined to Tasmanian waters. Other species were often taken by commercial whitebait fishermen in Tasmania, but according to Blackburn (1950) (who is responsible for providing most of our biological knowledge of this species), at least 95% of the catch was of L. sealii. Hence within this section where the term whitebait is used it refers to L. sealii unless otherwise stated.

The species was first described by Johnston (1883) and the genus Lovettia was established by McCulloch (1915). The best description of the species is given by McDowall (1971a).

6.1.1 Distribution within the State.

Blackburn (1950) mapped the distribution of this species in Tasmania and found that it did not occur on any of the Bass Strait Islands. He recorded it from the Duck River to the New Great Forester River on the north coast and from the Esperance River to Blackmans Bay in the south. This distribution was essentially followed by Frankenberg (1974) who also noted unconfirmed reports of the species from some west coast rivers. Lynch (1970) records that good deposits of whitebait ova were seen in the Arthur River, hence I assume that the species occurs there. For records from particular rivers the reader is referred to Blackburn (1950), Frankenberg (1974) and the annual reports of the Inland Fisheries Commission for the Years 1961-2, (Hobbs 1961, 1962) and 1965-77 (Lynch 1965-1977).

6.1.2 Habitat.

Much of the life of the whitebait is presumably spent in the sea or lower estuaries and details of its habitat during this stage are unknown. When the species does come under observation during its spawning migration it cannot be designated a specific habitat apart from saying that it moves into the upper estuaries, probably reaching as far up as the lower rapid sections in the rivers. Blackburn (1950) stated that the fishery for whitebait was usually in, or just above the estuary's delta if such a delta existed in a river (further upstream in the Huon and the Derwent).

The movements of whitebait during their marine phase are unknown.

6.1.3 Food and Feeding Behaviour.

Blackburn (1950) records that some whitebait were found to be feeding in each of the four stages of maturity he assigned to his specimens.

In a sample of 1200 fish examined only 8.4% (63 males and 38 females) contained food. The stomach contents according to Blackburn, "comprised the eggs and fry of Lovettia itself, small purplish amphipods, and various insects, including mayfly and stonefly nymphs, caddis-fly larvae, free-living dipterous pupae, and (in one instance) a juvenile cockroach."

6.1.4 Life History.

The whitebait is only usually encountered as a near mature or mature adult during their spawning migration, or as a very small larvae. Blackburn (1950) concluded that there was only one year of growth between these two stages. However, details of the life history of the whitebait during its growth to maturity are unknown. Blackburn sexed and measured over 78,000 whitebait during his study.

6.1.4.1 Growth and age.

By analysis of otoliths Blackburn (1950) determined that most of the spawning whitebait were one year old with a very small percentage (0.001%) of two year old mainly female (91%) fish. He does not indicate whether the latter fish have survived spawning or are delayed spawners. During their one year the whitebait reached a size of 35-60 mm in the north of the state and 33-55 mm in the south. The mean length of male fish was found to be less than that of females and the southern whitebait were, on average, shorther than the northern fish. Scott (1971a)

gave median values of a small sample of whitebait as 47.1 mm (male) and 50.1 mm (female). The two year old fish reached a maximum size of 70 mm so that the overall range of size for the species observed by Blackburn was 33-70 mm.

Blackburn gives the length frequency polygons for four series of male and female whitebait collected throughout the breeding season and from both northern and southern rivers. It is apparent from these that the length frequency distributions have a single mode and that there is no significant change in length with time for the one river in the same season. That is, although the migration is spread over some three months, (usually about late August to early November), all fish are of about the same average length on migration into a particular river irrespective of the time of capture in the season.

6.1.4.2 Pigmentation.

From the commercial point of view the development of pigmentation in whitebait is very important. Blackburn (1950) stated that, "although the Huon was the first river in which whitebait were taken for canning, the demand for the fish of this area declined when it was found that whitebait of a lighter colour could be taken abundantly in the northern streams." Blackburn gives details of the stages of development of pigmentation in the migrating whitebait and also relates this to stage of maturity of the fish. He concluded that increased pigmentation is generally concurrent with successive maturity stages irrespective of locality and that sou thern fish are slightly more

pigmented than northern fish of the same maturity stage. He attributes part of the darker colour of male fish after spawning to the fact that the darkly coloured peritoneum becomes visible externally once the fish have spawned and further lose condition.

Blackburn further concluded that although the whitebait of the Huon River were generally unacceptable for canning because of their dark colour this was largely a result of the fishing site. He stated that this site was too far up the river and that predominantly spent fish were being caught compared to unspent, and consequently less heavily coloured fish from other rivers. He showed that fish collected further downstream in the Huon were of better colour and condition than those caught upstream.

6.1.4.3 Sex ratio and sexual dimorphism.

Blackburn (1950) found that the male:female ratio in samples he collected was extremely variable. He found from 4 to 6893 males per 100 females in various samples in the northern rivers and ratios of similar order for southern rivers. The overall ratio was 2.25:1 male:female with little variation between the north and the south.

Lovettia sealii shows marked sexual dimorphism in the urinogenital system and parts of the alimentary tract and the sexes can be easily distinguished externally (Blackburn 1950). The urinogenital and alimentary system of male and female whitebait are figured by Blackburn (1950) and further details of the development of the alimentary and urinogenital

systems are described. Blackburn also found that the males had larger pectoral fins, usually more vertebrae and tended to be more heavily pigmented than females of the same maturity stages. Scott (1971a) lists a further difference in that the ventral fins of the male are also larger than those of the female.

6.1.4.4 Maturation and fecundity.

Blackburn (1950) found that the whitebait could generally be classified into four maturity stages and he lists the criteria he used for this classification. He found that the females were generally less advanced in maturity than the males but this may merely have been a function of his maturity criteria. Also the fish were only encountered late in their life cycle and these stages are greatly compressed for this species.

Blackburn found that the number of large eggs was positively correlated with size of fish. The largest number of eggs found in a single female was 310 (length 54 mm). He gives a table of mean number of eggs in samples of full females of 40-51 mm length (increasing in 1 mm intervals). A similar fecundity was also recorded by Fairbridge (1949).

6.1.4.5 Breeding biology.

The actual spawning act has not been observed and it is not known wether the eggs are fertilized before or after deposition (Blackburn 1950). The eggs are sticky on extrusion and are found in large numbers on vegetaion-free surfaces below low water level,such as stones, logs

and submerged branches. Scott (1968) states that the eggs may "float on the surface or become attached to aquatic plants, logs and submerged objects." Anon. (1944) wrote that "The eggs are to be found adhering in clusters to submerged twigs, rushes, piles and river plants at the time the runs are in progress." Blackburn (1950) states that the fishing and spawning areas are practically identical in all rivers except the Huon. These spawning areas are given by Blackburn as the estuarine delta area of the stream. He does not further define this area for rivers other than the Huon where the spawning site is given as in the deltaic islet area near Cradoc. Fairbridge (1949) states that Lovettia "spawns once, at or above the point of mixture of salt and freshwater." Blackburn found that chlorinities in the actual fishing areas ranged from 0.02 to 1.18 p.p.t. with 74% of these being 0.10 p.p.t. or less.

6.1.4.6 Embryology.

Blackburn (1950) stated that "The fertilised eggs are the same size as the ripe ovarian eggs." The diameter of the eggs at maturity was given as 1.1 mm. Blackburn reported on other unpublished studies that showed that the incubation period varied from 15 - 23 days at room temperature. The larvae artificially hatched by V.V. Hickman (Blackburn 1950) measured 5.8 mm and most of the yolk had been absorbed. Blackburn collected larvae in the Huon River ranging up to 7 mm in length. The only differences of these from the newly hatched stage being the complete absorption of the yolk, the appearance of caudal and pectoral fin rays and some further development of ventral pigmentation.

6.1.4.7 Migrations.

The whitebait undergo two major migrations the first of which is probably purely a passive drift to the sea via the river currents. The migration into the estuaries from the sea is an active movement often against very strong currents. The whitebait are present in the rivers around springtime and Blackburn (1950) gives the time for the northern season as usually October. Some Lovettia are also taken in late July-August and a few in November. He states that the season in the south is also approximately three months from mid September to mid December. Blackburn states that "There are no records of catches at any earlier or later date, although shoals have been reported in the Huon in August". However, in the whitebait catch details in the annual reports of the Tasmanian Inland Fisheries Commission (Lynch 1966-72) L. sealii is recorded consistently from the Huon River and often from the Derwent in August but no Lovettia were caught in any river in December.

No details are available on factors effecting the migration into the estuaries. It appears that there may be some post spawning movement further upstream from the spawning site as evidenced by the spent condition of most of the whitebait caught in the upper Huon River.

6.1.5 Disease, Parasites and Natural Predation.

No diseases have been recorded for Lovettia but several parasites have been noted. The trematode Parahemiurus lovettia was described by Crowcroft (1947) from the intestine of

Lovettia. Other parasites listed by Blackburn (1950) are the trematode Acanthostomum present in subdermal cysts, the larval nematode Capsularia marina (L) from the oesophagus and coelom and the immature stage of a calinoid copepod from the pelvic and anal fins. (Blackburn acknowledges Prof. T. H. Johnston and Dr. A. G. Nicholls for assistance with identification of the parasites).

Blackburn lists several fish which prey on Lovettia. These are barracouta (Thyristes atun), rock cod (Physiculus barbatus), Australian salmon (Arripus trutta), school shark (Notogaleus rhinophanes), mullet (Agonostomus forsteri), brown trout (Salmo trutta) and eels as well as terns and other aquatic birds.

6.1.6 Competition.

The estuarine trout fisherman would well know that the brown trout was quite fond of whitebait. However, Blackburn (1950) thought that the whitebait itself competes for food with the brown trout. He bases this on his examination of only Lovettia stomachs with food in them and as these constitute a very small proportion of the whitebait present, I don't think he can justify competition on this basis.

In his study of the trout fisheries of the north western rivers Nicholls (1958) considered that the relationship between the trout and whitebait in the estuary was a major factor in the success of trout anglers. In the years when whitebait were plentiful surface lures such as the fly and spinner were particularly successfull but when the

whitebait were scarce the trout reverted to bottom feeding and were less easily taken by the angler.

Natural competition does not appear to have been of major importance to the whitebait as they were extremely plentiful for at least 80 years after the introduction of trout and survived for much longer with other native fish. Many other species have been collected with Lovettia (see Anon 1944, 1968a; Scott 1936a, 1971a; Blackburn 1950; Lynch 1965a, 1965 to 1975; McDowall 1971a) but no evidence of competition or interaction between these species has been observed although they move in multi-specific schools. The species, apart from Lovettia sealii, recorded by the various authors are as follows: Galaxias attennatus (G. maculatus), G. truttaceus, G. weedoni (G. brevipinnis), Retropinna tasmanica, the gobies Tasmanogobius lordi and Ctenogobius tamarensis (Favonogobius tamarensis) and the atherinid Atherinosoma tamarensis.

6.1.7 Use as Food.

The whitebait has been valued as food since before the 1940's. Blackburn (1950) states that the Tasmanian whitebait fishery effectively dates from 1941. Scott (1936a) records that whitebait could be purchased in Launceston shops in September 1934 and 1935. The fish were from the Tamar and Mersey rivers respectively and the going price was "between two hundred and three hundred fish for a penny."

Blackburn has compiled data on the whitebait fishery since the operations became established and these data

(1941-1948) are tabulated along with the number of licensed fishermen and the catch per license (scoop) since licenseing was introduced in 1944 (Blackburn 1950). The catch was readily canned as the fishery was during a slow period for the canneries. The fishery reached peak production in 1947 with a catch of 483,076 kg, however, the catch per scoop was down on previous years. The subsequent years saw a slump in the fishery and it declined to a catch of only 1814 kg. in 1956 (Lynch 1965), with a slight recovery in the following year but a subsequent decline to 2,704 kg in 1973 (Lynch 1974) after which the season was closed. Further data on the yearly catches of the whitebait are given by Hobbs (1961) for years 1943-1960 and for successive years from 1964 to 1973 by Lynch (1965 to 1974).

Blackburn (1950) carefully considered the implications of his findings and concluded that the exploitable margin in the fishery was probably exceded thus causing depletion. He suggested that the season be closed in 1949 (this was done) and that the fishery be carefully monitored in future. He further suggested that a management system based on annual quotas be imposed. There was an open season again in 1950 but catches did not approach the quotas suggested by Blackburn. It appears that the fishery was allowed to progress with little positive action being shown by its administrators. Hobbs (1961) reported on the "destruction of the whitebait fishery" and later (Hobbs 1962) proposed that the regulations concerning the fishery be ammended to give control to the Inland Fisheries Commission. In 1965

the fishery was finally brought under the control of this body (Lynch 1966). The changing nature of the fishery was observed by Lynch (1965) in that the percentage of L. sealii in the catch was no longer anywhere near the 95% mark observed by Blackburn (1950) in his samples. But despite the continued decline in catch nothing was done until after the 1973 season when it was finally proposed to close the fishery for the 1974-76 seasons (Lynch 1974). However after this period there was still no appreciable recovery and the fishery has remained closed to date with no adequate research being done in the meantime.

The low level to which the whitebait stocks have dropped accompanied by the ever increasing pollution of their estuarine breeding sites does not look encouraging and the return to its former state of the once profitable fishery appears unlikely.

## 6.2 Retropinna tasmanica; (Tasmanian smelt).

The smelt is one of the smallest of the native fishes. It is similar in appearance, and also in its distinctive cucumber odour, to the grayling. The genus Retropinna was first described by Gill (1862) and the Tasmanian species R. tasmanica was described by McCulloch (1920) and McDowall (1979) also gives a good description of the species. Several other fishes are referred to as smelt but this term is used only for R. tasmanica below.

6.2.1 Distribution within the State.

A map of the distribution of R. tasmanica in Tasmania is given by Frankenberg (1974). The statement by Frankenberg that "R. semoni is now established in the Plenty River" is incorrect as it was only introduced into Tasmania (Lynch 1965) and held since then in an isolated pond. Frankenberg records R. tasmanica from the rivers of the north and south-east of the state rarely far inland. He also records a landlocked population from the Richmond area. McDowall (1979) gives a slightly more recent map but the basic distribution pattern is still essentially similar to that of Frankenberg (1974) although they probably occur over a somewhat wider range than recorded.

6.2.2 Habitat.

Frankenberg (1974) states that, "Juvenile life is probably passed in brackish water or the sea", and that the species is "prevalent in estuaries in the summer months." Frankenberg also records the existence of a landlocked population above the Coal River wier. I also know of populations of this species in isolated farm dams in southern Tasmania, hence the species appears to be able to live as an anadromous fish or in an entirely freshwater habitat. No other work has been published on the habitat of this species.

6.2.3 Food and Feeding Behaviour.

Bennison (1975) examined the stomach contents of five smelt from the Coal River in the November of 1975.

Lake and Bennison (1977) examined six specimens from the Coal River collected in October 1974. In both these cases the major food items were dipteran (Chironomidae in the latter study at least) and trichopteran larvae with some amphipods, hemipterans and coleopteran larvae also eaten. This diet is similar to that recorded for R. osmeroides (R. retropinna) in New Zealand by Allen (1951) who found its diet consisted largely of chironomid larvae and pupae. However Lake (1971) found that the Australian mainland species R. semoni fed on algae and plankton.

No further information is available on the diet of the smelt in Tasmania.

6.2.4 Life History.

The life history of R. tasmanica has not been studied in any detail and very little is known of this species at all. The development of the eggs and early larvae of R. semoni is described by Milward (1969) and the development of R. tasmanica is probably similar. McDowall (1979) records that the largest anadromous R. tasmanica he measured was 67 mm LCF and a landlocked specimen measured about 71 mm LCF. No other growth details are available.

Sexual dimorphism is apparent in all retropinnids (Woods 1963, 1968b; McDowall 1972a, 1979). Details of this were first published by McMillan (1961) for R. anisodon (Stokellia anisodon). McDowall (1979) states that "sexual dimorphism, as described for R. retropinna is quite clearly seen in samples of mature to ripe R. semoni and R. tasmaniça."

These differences are that the fins and mid-ventral abdominal keel are larger in males than females and that nuptial tubercles are more prominent and widespread in the males. Another interesting feature of the retropinnids is that only the left gonad of both sexes is developed (McDowall 1979). No other aspects of the development or life history of the Tasmanian smelt are known.

6.2.5 Diseases, Parasites and Natural Predation.

No diseases or parasites have been recorded from the smelt. Since this fish is often present with the Lovettia schools it is most probable that natural predators of those fishes would at times also become predators of smelt. Hence the predators mentioned in the previous section could be included here and the reader is referred to that section for details.

6.2.6 Use as Food.

The presence of small R. tasmanica in Tasmanian whitebait schools has been recognised by many authors (Johnston 1883; Anon 1944, 1968a; Blackburn 1950; Lynch 1965a, 1966; Scott 1971a; Lake 1971; McDowall 1971a). Scott (1971a) points out that Johnston was mistaken in saying that the fish he (Johnston) called R. richardsoni was the major constituent of the whitebait. But Johnston may have been referring to another run as he indicates that the fish were plentiful in the Tamar in the months of February and March which is not the normal migration

time of Lovettia.

Lynch (1966) gives details of the whitebait catch for 1965 which includes catches of 6 and 18 kg. of R. tasmanica from the Mersey in September and October respectively.

## 6.3 Prototroctes maraena; (Australian grayling).

The grayling is one of the rarer Tasmanian native fishes and has been regarded by Lake (1971) as a "seriously threatened species." He considered that it may well follow the New Zealand P. oxyrhynchus into extinction. However the species is still occassionally taken in Tasmania and a series of specimens has recently been taken from both Victoria and New South Wales.

P. maraena is also known as cucumber mullet, cucumber herring, Yarra herring and Australian grayling. It was first described by Gunther in 1864; the most recent description of the species is given by McDowall (1976c). The young grayling may be confused with the smelt Retropinna tasmanica and it also shares the peculiar cucumber smell with this fish.

### 6.3.1 Distribution within the State.

Frankenberg (1974) and McDowall (1976c) give maps showing the distribution of P. maraena in Tasmania. They show the grayling to be (or have been) present in most coastal streams with the exception of some of the west coast streams. The grayling was reported from the Gordon system in the Royal Commission on the Fisheries

of Tasmania (Seal et al. 1883) and a specimen was recently collected from that river (Lynch 1977). Thus the grayling probably had a statewide distribution in coastal streams. In the last twenty years specimens have been taken spasmodically from some rivers in most parts of the state but not in large numbers. However Bishop and Bell (1978b) cite a personal communication from P. Last which indicates the presence of schools of small P. maraena in Tasmanian estuaries. These are on the west coast of Tasmania and on King Island.

### 6.3.2 Habitat.

A large sample of grayling was collected from the Shoalhaven River in New South Wales during December 1976. The majority of the fish were collected from what Bishop and Bell (1978a) describe as a "torrential lotic environment", with water velocities of 2-4 m/sec, but they were uncertain wether this was the usual habitat of the fish or a result of a concentration below the stream barrier.

### 6.3.3 Food and Feeding Behaviour.

Before the study of Jackson (1976) there were only brief references to the diet of P. maraena (Allport 1869, 1870; Johnston 1883, 1891; Stead 1903) which suggested that the grayling was at least partly herbivorous, basing this statement on the morphology of the alimentary tract. The closely related New Zealand species was reported to feed on plant material at certain times (Phillipps 1926; Best 1929).

Recently the stomach contents of 22 specimens of P. maraena were examined from the Mitchell River in Victoria (Jackson 1976). It was found that aquatic insect larvae were the most important food item consumed although plant material was found in approximately half the stomachs.

The largest sample of grayling examined for stomach contents was done by Bishop and Bell (1878b). This was a sample of 312 fish collected from the Shoalhaven River in New South Wales on 29th November 1976. In this study cladocerans were found to be the dominant food item comprising 52% by volume of the food taken and were present in every stomach examined. Algae (predominantly an unidentified blue-green) comprised 24% of the stomach volume overall and up to 90% in some stomachs.

Bishop and Bell (1978b) found that other samples of grayling collected at different dates were feeding largely on aquatic insects with no algae present. Hence the diet appears to change somewhat probably depending on food availability.

No significant differences were found in the diets of male and female fish by Bishop and Bell (1978b) but some changes were observed in relation to year classes. The 1+ fish consumed more cladocerans whereas the 2+ fish consumed more chironomids and algae.

### 6.3.4 Life History.

Since the early work on P. maraena by Allport and

Saville-Kent there has been a considerable gap until the recent study by Bishop and Bell. Few details on the population structure of grayling were available until this latter work.

6.3.4.1 Age and growth.

Many authors have given estimates of the maximum size attained by the grayling eg. Seal et al. (1883), Stead (1903) and Lake (1971) estimate the maximum length at 300mm and Whitley (1957, 1960) and Pollard (1969) give the length at 330 mm. McDowall (1976c) measured specimens up to 250 mm LCF, Tunbridge (1972) to about 245 mm and Jackson (1976) to 235 mm. Bishop and Bell (1978b) calculated a maximum length for grayling in the Shoalhaven River which was 278.8 mm LCF. Their maximum observed length was 219 mm LCF. They considered that as this river was at the northern end of the range for the species, grayling may reach a larger size further south.

Most of the early authors mentioned above give the maximum weight attained by the grayling as about 340-450 g. Maximum weight observed by Bishop and Bell (1978b) was 84.9 g.

The study by Bishop and Bell (1978b) is the only one to give any detail of the growth and population structure of the grayling. Length frequency distributions of a sample of 312 fish collected on 29th November 1976 are given. Part of this sample is broken up into male and female components. No significant differences were found between the male and female length histograms.

There were two length groups in the main sample of fish, 113-165 mm and 172-219 mm. Bishop and Bell (1978b) considered that these corresponded to 1+ amd 2+ age groups and these data are supported by Tunbridge (1972) for Victorian fish. Bishop and Bell also found a 79 mm specimen on 22 December 1976 which they consider was in the 0+ age group. They further substantiate these groupings by analysis of otoliths.

These authors used data obtained from the fish length/otolith radius relationship to calculate the estimated maximum length of the grayling (=278.8$\pm$29.3mm) the estimated spawning dates (early February to early March).

Length-weight relationships are also given by Bishop and Bell (1978b). The main sample of fish ranged in weight from 11.3 to 84.9 g. with the 79 mm specimen mentioned above weighing 3.8 g. The relationship for the combined sexes was given as:-

$$W = 3.6 \times 10^{-6} L^{3.174} \qquad r = 0.98$$

Where W=weight in grams
L=length (LCF) in millimetres
r=correlation co-efficient.

6.3.4.2 Maturation sex ratio and fecundity.

Tunbridge (1972) found grayling which he considered to be two year old "in a ripe condtion and obviously ready to spawn in a short time." Bishop and Bell (1978b) also found that the grayling matured at the end of its second year but judging from the relative

gonadosomatic indices of 1+ and 2+ fish they considered that the 2+ fish matured earlier.

The sex ratios were found to be almost equal in the 1+ age class (Bishop and Bell 1978b). However there was a marked change in the 2+ group where the ratio was 2:1 female to male. This indicates that there is a greater mortality of male fish than female fish during the 2 year old spawning.

Bishop and Bell (1978b) quote some unpublished data of Jackson on the fecundity of P. maraena in Victoria. The highest estimated fecundity was 68,400 which is a high value for salmonids.

6.3.4.3 Breeding biology.

There has been considerable speculation on the life history of the grayling which has largely been confounded by the apparent scarcity of the fish in recent years. Allport (1870) and Saville-Kent (1886a,b) reported on early investigations into artificial propagation of the species. The breeding cycle has been speculated upon in turn by Johnston (1891), Stead (1903), Lord and Scott (1924), Tunbridge (1972), Frankenberg (1974), McDowall (1976c) and Bishop and Bell (1978b).

None of these authors provide any concrete data on migrations (if any) or spawning site and behaviour but it is generally agreed that the spawning takes place somewhere in fresh or brackish water and that the early juvenile life is probably spent in the sea.

The fact that the ova will develop in fresh-water was proven by Allport (1870) and examined further by Saville-Kent (1886a,b) who undertook to transfer fertilised ova from the Mersey to the Derwent River in Tasmania. Saville-Kent (1886b) found that the eggs of P. maraena are less than 1 mm in diameter when ripe. They are non-adherent, are pale yellow in colour and sink to the bottom on extrusion. The yolk sac is almost fully absorbed upon hatching hence there is no alevin stage. The length of the fish is about 6.5 mm at this stage.

Saville-Kent (1886a) found the spawning season to be in February to April. McDowall (1976c) found this in agreement with the maturity stages of specimens he examined. The recent grayling samples of Bishop and Bell (1978b) did not include fish taken during the spawning season but by using theoretical methods they concluded that spawning would take place in early February to early March.

The grayling appear to suffer heavy mortality after spawning particularly the 2 year old group and it appears that no fish survive beyond 3 years (Bishop & Bell 1978b). It is possible that the grayling may not survive spawning at all and that the fish which survive to three years of age did not spawn at age two. This situation probably occurs with the closely related Lovettia sealii (Blackburn 1950) and Retropinna retropinna (McDowall 1976c).

The spawning site or any details of spawning behaviour have not been observed for this species.

6.3.5 Anatomy and Histology.

McDowall (1974) remarked on the specialised dentition of both species of southern hemisphere grayling. This author also gives details of the alimentary tract which he found to be longer than other salmonids. McDowall (1974) considered both of these features to be adaptations for at least some degree of algal feeding.

Bishop and Bell (1979b) further support McDowalls findings in their examination of the alimentary tract. They related the gut length to that of other fish species and also examined the length of parts of the gut in relation to fish age. They found a change in the relative proportions of the various parts of the gut which they related to the changes in the algal content of the graylings diet with age mentioned in the feeding section of this chapter.

Bishop and Bell (1978b) also give histological details of both ovaries and testes of the grayling.

6.3.6 Disease, Parasites and Natural Predation.

Johnston (in Seal et al. 1883) reports that the disappearance of the grayling in Tasmania was due to an epidemic. He reports seeing thousands of them "floating down the Mersey, about the same time that they disappeared in all the other rivers of Tasmania. The fins, gill-covers

and eyes were covered with a fungus." Johnston further reports that the fungus was not observed in any other year. McDowall (1976c) and Bishop and Bell (1978b) considered that the phenomenon recorded by Johnston could have been a post spawning mortality.

No other diseases or incidences of parasitism or natural predation have been recorded for the grayling.

6.3.7 Competition.

As pointed out by McDowall (1976c) the decline in numbers of P. maraena began quite early after the European settlement of Tasmania. McDowall states that; "Reasons for its decline are quite unknown, but it seems most likely to be related to habitat disruption caused by deforestation, and the introduction of brown trout." I do not think these factors fully explain the uniformly widespread reduction in numbers which occurred as brown trout introduction and serious deforestation had not taken place in some of the areas where the grayling was becoming rare by the 1880's.

McCulloch (1914) suggested that the liberation of Carassius auratus in Australian waters may have caused the decline but this was discounted by McDowall (1976) because of the habits of this fish. Also carp have never been common in the colder Tasmanian rivers.

Lake (1971) stated that "there is little doubt that wiers and dams on coastal rivers could play some part in adversely affecting the fish." This is indeed a major

factor hindering any reestablishment of the grayling on our rivers but was probably not a major factor in the early decline of the species.

The decline of the two grayling species was widespread, simultaneous, and in the case of the New Zealand species, P. oxyrhynchus continued to apparent extinction. I don't think that any of the theories completely explain the decline but it appears certain that man's interference has in some way attributed to it and judging by the 300 plus specimens killed during dam building operations in New South Wales (Bishop & Bell 1978a,b) their actions will continue to cause concern.

The grayling has been given some protection in Tasmania where its capture is now illegal but sightings still remain rare.

6.3.8 Use as Food.

The grayling was highly regarded as both a fine sporting and table fish (Seal et al. 1883; Johnston 1883; Stead 1903). It was commonly taken by fly-fishermen often in large numbers. Seal et al. (1883) record that one angler took 46 dozen of them in 36 hours. Fishing for the grayling is now prohibited in Tasmania.

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